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Aerocomp, Inc., Costa Mesa, CA

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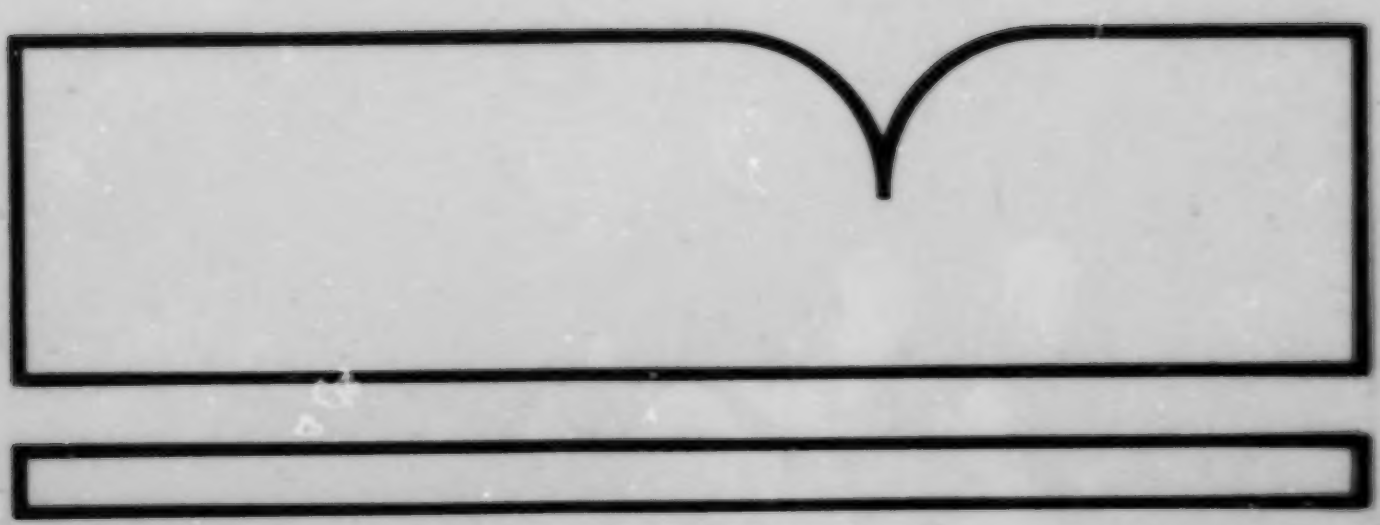

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User's Guide

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INPUFF is a Gaussian INtegrated PUFF model. The Gaussian puff diffusion equation is used to compute the contribution to the concentration at each receptor from each puff every time step. Computations in INPUFF can be made for a single point source at up to 25 receptor locations. In practice, however, the number of receptors should be kept to a minimum. In the default mode, the model assumes a homogeneous wind field. However, the user has the option of specifying the wind field for each meteorological period at up to 100 user-defined grid locations. Three dispersion algorithms are utilized within INPUFF for dispersion downwind of the source. These include Pasquill's scheme as discussed by Turner (1970) and a dispersion algorithm discussed by Irwin (1983), which is a synthesis of Draxler's (1976) and Cramer's (1976) ideas. The third dispersion scheme is used for long travel times in which the growth of the puff becomes proportional to the square root of travel time. A software plotting package is provided to display concentration versus time for a given receptor and the puff trajectories after each simulation time.

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INPUFF - A SINGLE SOURCE GAUSSIAN PUFF DISPERSION ALGORITHM
User's Guide

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AFFILIATION

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PREFACE

One area of research within the Meteorology and Assessment Division is development, evaluation, validation, and application of models for air quality simulation, photochemistry, and meteorology. The models must be able to describe air quality and atmospheric processes affecting the dispersion of airborne pollutants on scales ranging from local to global. Within the Division, the Environmental Operations Branch adapts and evaluates new and existing meteorological dispersion models and statistical technique models, tailors effective models for recurring user application, and makes these models available through EPA's UNAMAP system.

INPUFF is an integrated puff model with a wide range of applications and flexibility. It is designed to model semi-instantaneous or continuous point sources over a spatially and temporally variable wind field. A software plotting package is also provided to display concentration versus time plots for each receptor and the puff trajectories after each simulation time.

Although attempts are made to thoroughly check computer programs with a wide variety of input data, errors are occasionally found. Revisions may be obtained as they are issued by completing and returning the form on the last page of this guide.

The first four sections of this document are directed to managers and project directors who wish to evaluate the applicability of the model to their needs. Sections 5, 6, 9, and 11 are directed to engineers, meteorologists, and other scientists who are required to become familiar with the details of the model. Finally, Sections 7 through 11 are directed to persons responsible for implementing and executing the program.

Comments and suggestions regarding this publication should be directed to:

Chief, Environmental Operations Branch
Meteorology and Assessment Division (MD-80)
Environmental Protection Agency
Research Triangle Park, NC 27711.

Technical questions regarding use of the model may be asked by calling (919) 541-4564. Users within the Federal Government may call FTS 629-4564. Copies of the user's guide are available from the National Technical Information Service (NTIS), Springfield, VA 22161.

The magnetic tape containing FORTRAN source code for INPUFF will be contained (along with other dispersion models) in future versions of the UNAMAP library, which may be ordered from Computer Products, NTIS, Springfield, VA 22161 (phone number: (703) 487-4763).

This user's guide is intended to be a living document that is updated as changes are required. Each page of the User's Guide to INPUFF has a month and year typed in the lower right hand corner. Future revisions to this document will be indicated on this page, and every page that is changed due to the revision will have a new date printed in the lower right hand corner. The current version number of INPUFF is 84107. The current version number of INPUFF and the date associated with it will be given in the preface of the user's guide. The version number is also maintained in the source code allowing the user to confirm that his user's guide and source code are current.

ABSTRACT

INPUFF is a Gaussian INtegrated PUFF model. The Gaussian puff diffusion equation is used to compute the contribution to the concentration at each receptor from each puff every time step. Computations in INPUFF can be made for a single point source at up to 25 receptor locations. In practice, however, the number of receptors should be kept to a minimum. In the default mode, the model assumes a homogeneous wind field. However, the user has the option of specifying the wind field for each meteorological period at up to 100 user-defined grid locations. Three dispersion algorithms are utilized within INPUFF for dispersion downwind of the source. These include Pasquill's scheme as discussed by Turner (1970) and a dispersion algorithm discussed by Irwin (1983), which is a synthesis of Draxler's (1976) and Cramer's (1976) ideas. The third dispersion scheme is used for long travel times in which the growth of the puff becomes proportional to the square root of travel time. A software plotting package is provided to display concentration versus time for a given receptor and the puff trajectories after each simulation time.

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SYMBOLS AND ABBREVIATIONS

Dimensions are abbreviated as follows:
m = mass, l = length, t = time, K = temperature

C	-- pollutant concentration (m/l^3)
d	-- stack inside diameter (l)
F	-- buoyancy flux parameter (l^4/t^3)
f_y	-- nondimensional function of travel time for horizontal dispersion
f_z	-- nondimensional function of travel time for vertical dispersion
g	-- acceleration due to gravity (l/t^2)
H	-- effective height of plume (l)
h	-- stack height above ground (l)
h'	-- stack height adjusted for stack downwash (l)
L	-- mixing layer depth (l)
Q	-- emission rate (m/t)
r	-- radial distance from center of puff (l)
s	-- stability parameter (t^{-2})
t	-- travel time (t)
T	-- ambient air temperature (K)
T_s	-- stack gas temperature (K)
u	-- wind speed at stack top (l/t)
v_s	-- stack gas exit velocity (l/t)
x	-- downwind distance (l)
x_f	-- distance to final rise (l)
x^*	-- distance at which atmospheric turbulence begins to dominate entrainment (l)
y	-- crosswind distance (l)
z	-- height above ground (l)
Δh	-- plume rise (l)
ΔT	-- temperature difference between ambient air and stack gas (K)
$(\Delta T)_c$	-- temperature difference for crossover from momentum to buoyancy-dominated plume (K)
$\partial\theta/\partial z$	-- vertical potential temperature gradient of a layer of air (K/l)
π	-- pi, 3.14159
σ_a	-- standard deviation of the horizontal wind angle (radians)
σ_e	-- standard deviation of the vertical wind angle (radians)
σ_r	-- horizontal dispersion parameter (l)

σ_{ro} -- initial horizontal dispersion (l)
σ_v -- standard deviation of the horizontal crosswind component of the wind (l/t)
σ_w -- standard deviation of the vertical component of the wind (l/t)
σ_x -- dispersion parameter in the downwind direction (l)
σ_y -- lateral dispersion parameter (l)
σ_z -- vertical dispersion parameter (l)
σ_{zo} -- initial vertical dispersion (l)

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In addition to the listed authors of the user's guide, other Aerocomp personnel made important contributions to the document. Source code review and comment optimization were made by Mr. Frank V. Hale III, who also designed the sensitivity analysis. Ms. Sarah Cunningham prepared all technical illustrations and produced the final document. Editorial review was provided by Ms. Vicki Catalano.

EXECUTIVE SUMMARY

The INPUFF (INtegrated PUFF) computer code is designed to simulate dispersion from semi-instantaneous or continuous point sources over a spatially and temporally variable wind field. The algorithm is based upon Gaussian puff assumptions including a vertically uniform wind direction field and no pollutant removal or chemical reactions. INPUFF can estimate concentrations from a single point source at up to 25 receptors.

INPUFF utilizes three distinct dispersion algorithms. For short travel time dispersion, the user has the option of using either the Pasquill-Gifford (P-G) scheme (Turner, 1970) or the on-site scheme (Irwin, 1983). The third dispersion algorithm was designed for use in conjunction with the P-G or on-site schemes. It is used for long travel times where the growth of the puff is assumed proportional to the square root of travel time.

Features of the INPUFF computer code include:

- Optional stack downwash;
- Wind speed extrapolated to release height;
- Temporally variable source characteristics;
- Temporally and spatially variable wind field (user-supplied);
- Consideration of terrain effects through user-supplied wind field; and
- Consideration of moving source.

In addition, a software plotting package has been provided to display concentration versus time for a given receptor and the puff trajectories after each simulation time.

In the interest of stimulating research, a simple sensitivity analysis of several user options is provided in Section 9. Tips on minimizing computer costs without sacrificing accuracy are also suggested.

SECTION 1

INTRODUCTION

INPUFF is a Gaussian plume, integrated puff model with a wide range of applications. The implied modeling scale is from tens of meters to tens of kilometers. The model is capable of addressing the accidental release of a substance over several minutes, or of modeling the more typical continuous plume from a stack. Several requests to the Environmental Operations Branch for assistance in modeling the air quality downwind of incineration ships prompted the development of an integrated puff model. INPUFF is, therefore, capable of simulating moving point sources as well as stationary sources.

Computations in INPUFF can be made for a single point source at up to 25 receptor locations. In practice, however, the number of receptor locations should be kept to a minimum. INPUFF is primarily designed to model a single event during which one meteorological transition period may occur, such as, going from afternoon to evening conditions. Up to 144 separate meteorological periods of the same length may be used to characterize the meteorology during the event; this provides a time resolution that ranges from minutes to an hour. The user has the option of specifying the wind field for each meteorological period at up to 100 grid locations or allowing the model to default to a homogeneous wind field. Three dispersion algorithms are used within INPUFF for dispersion downwind of the source. The user may use the Pasquill-Gifford (P-G) scheme (Turner, 1970) or the on-site scheme (Irwin, 1983) for short travel time dispersion. The on-site scheme, so named because it requires specification of the variances of the vertical and lateral wind direction, is a synthesis of work performed by Draxler (1976) and Cramer (1976). The third dispersion scheme is for long travel times in which the growth of the puff becomes proportional to the square root of time. A software plotting package has also been provided to display concentrations versus time for a given receptor and the puff trajectories after each simulation period.

This document is divided into three parts, each directed to a different audience: managers, dispersion meteorologists, and computer specialists. The first four sections are aimed at managers and project directors who wish to evaluate the applicability of the model to their needs. Sections 5, 6, 9, and

11 are directed toward dispersion meteorologists or engineers who are required to become familiar with the details of the model. Finally, Sections 7 through 11 are directed toward persons responsible for implementing and executing the program. A listing of the FORTRAN source statements and a detailed description of the plume rise algorithm are included in the two appendices.

SECTION 2

DATA-REQUIREMENTS CHECKLIST

INPUFF requires data on user options, grid dimensions, sources, meteorology, receptors, and plotter control. The user must indicate whether the following options are to be employed:

- Stack-tip downwash,
- Source update,
- User-supplied wind field,
- Intermediate concentration output, and
- Puff information output.

The dimension of the modeling grid must be specified. If the user-supplied wind field option is implemented, then the dimension of the meteorological grid along with the size of each grid rectangle must also be indicated. It is recommended that both grids be given a common origin. If a puff travels outside the modeling region, it is deleted from further consideration. If it travels outside the meteorological grid, but is still within the modeling region, the last wind experienced by the puff is used to advect it further.

Information required on the source includes the following:

- Location (km),
- Emission rate (g/sec),
- Physical stack height (m),
- Stack gas temperature (K),
- Stack diameter (m),
- Stack gas velocity (m/sec),
- Stack gas volume flow (m^3/sec), and
- Initial σ_r and σ_z (m).

Also the direction and speed of the source, if it is moving, must be provided as input.

The meteorological data needed for the computations are as follows:

- Wind direction (deg),
- Wind speed (m/sec),
- Mixing height (m),
- Stability class (dimensionless),
- Standard deviation of elevation angle (radians),
- Standard deviation of azimuth angle (radians),
- Ambient air temperature (K), and
- Anemometer height (m).

The user has the option of updating the meteorological information after each meteorological time period. The location and height of each receptor must be indicated. If dispersion is characterized by the on-site scheme, then the standard deviations of the azimuth and elevation angles are required.

The following information is required by the plot routines:

- Type of plot desired,
- Location of concentration versus time plots, and
- Plotting grid.

The plot routines were developed on a UNIVAC 1110 and use CALCOMP plotting software.

SECTION 3

FEATURES AND LIMITATIONS

Several requests to the Environmental Operations Branch for assistance in modeling the air quality downwind of incineration ships stimulated the development of INPUFF, a model capable of simulating a moving point source in a spatially variable wind field. The model also possesses the following features which increase its flexibility and range of application:

- Optional stack-tip downwash,
- Wind speed extrapolated to release height,
- Temporally variable source characteristics,
- Temporally and spatially variable wind field,
- Up to 25 receptors,
- Some consideration of terrain effects through the wind field, and
- Optional graphics display.

The implied modeling scale is from tens of meters to tens of kilometers. INPUFF is capable of addressing the accidental release of a substance over a short time period, or of modeling the more typical continuous plume from a stack.

Although INPUFF has several advantages over its continuous plume counterpart, it still retains several limitations, including:

- Wind direction constant with height,
- No consideration of pollutant removal or chemical reactions, and
- No explicit treatment of complex terrain.

Also, INPUFF has no provision for calculating the effect of a large area source or multiple point sources.

The table below presents a comparison of INPUFF features with those of other air quality models.

TABLE 1. A COMPARISON OF INPUFF TO OTHER COMMONLY USED AIR QUALITY MODELS

X -- used by model O -- optional	INPUFF	PTPLU	PTDIS	PTMTP	RAM	MPTER	CRSTER	VALLEY	PAL	MESOPUFF
MODEL TYPE										
Gaussian plume		X	X	X	X	X	X	X	X	
Gaussian puff	X									X[1]
GRID SIZE	100									1600
AVERAGING PERIOD										
Hour	O	X	X	X	X	O	X		X	O
3-hour	O				O	O	X		O	O
24-hour	O			X	O	O	X	O	O	O
Annual						O	X	O		
TYPE OF SOURCES										
Single stack	X	X	X	X	X	X	X	X	X	X
Multiple stacks				25	250	250	19[2]	50[3]	99	10
Area sources					100			50[3]	99	
Line sources									99	
RECEPTORS										
Number of	25		50	30	180	180	180	112	99	X[4]
Cartesian coordinates			X[5]		X	X				X
Cartesian coordinates w/ elevations	X			X		X			X	
Polar coordinates					X	X				
Polar coordinates w/ elevations						X	X	X		
Program generated grid					O					
METEOROLOGICAL DATA										
RAMMET preprocessor					X	X	X			
MESOPAC preprocessor										X
STAR file								X		
User specified	X		X	X	O	O		X	X	
Program generated		X								
POLLUTANT										
Non-reactive	X	X	X	X	X	X	X	X	X	X[6]
Half-life					O	O		O		
PLUME RISE										
Stack tip downwash	O	O			O	O	O			
Gradual plume rise		O		X	O	O	O	O	X	
Buoyancy-induced dispersion		O			O	O		O		
TERRAIN ADJUSTMENTS	O			O		O	O	O		O

(1) Specially suited for long range transport.
(2) Co-located stacks.
(3) Total of 50 point and/or area sources.
(4) Concentrations computed at each grid point and at up to 50 user-specified receptors.
(5) Concentrations computed at fixed downwind distances.
(6) Linear conversion of SO_2 to SO_4 and linear deposition of SO_2 and SO_4.

SECTION 4

BASIS FOR INPUFF

GAUSSIAN PUFF METHODOLOGY

A graphical representation of the INPUFF model is given in Figure 1. Here the first puff (the puff with the longest trajectory) was first exposed to east-southeast winds, followed by slightly stronger winds from the south and the south-southeast. The second puff was released at the time the winds shifted from east-southeast to south. The third puff was released when winds were from the south-southeast. The stability conditions need not be equal for the various time steps, though in the figure, stability is shown to be fairly constant with time (i.e., the rate of puff growth is constant over the time frame). INPUFF assumes $\sigma_x = \sigma_y$, thus puffs remain circular throughout their lifetime. Puffs A, B, and C represent the location of the three emitted puffs at time t_3.

In Gaussian-puff algorithms, source emissions are treated as a series of puffs emitted into the atmosphere. Constant conditions of wind and atmospheric stability are assumed during a time interval. The diffusion parameters are functions of travel time. During each time step, the puff centers are determined by the trajectory and the in-puff distributions are assumed to be Gaussian. Thus, each puff has a center and a volume which are determined separately by the mean wind, atmospheric stability, and travel time.

PLUME RISE

Plume rise is calculated using the methods of Briggs (see Section 5). Although plume rise from point sources is usually dominated by buoyancy, plume rise due to momentum is also considered. Building downwash, buoyancy-induced dispersion, and gradual plume rise are not presently treated by INPUFF.

Stack-tip downwash (optional) can be considered using the methods of Briggs. In such an analysis, a height increment is deducted from the physical stack height before momentum or buoyancy rise is determined. Use of this option primarily affects computations from stacks having small ratios of exit velocity to wind speed.

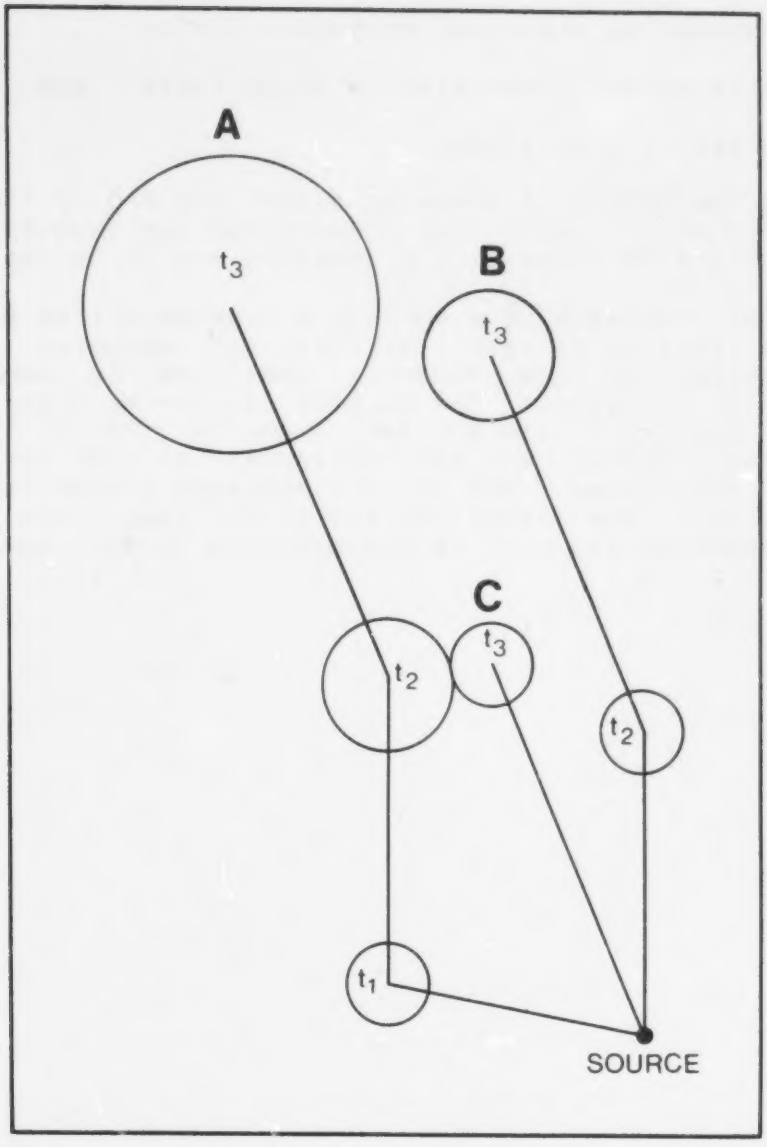


Figure 1. Gaussian puff model.

DISPERSION ALGORITHMS

Three dispersion algorithms are used within INPUFF for dispersion downwind of the source:

- P-G scheme as discussed by Turner (1970),
- On-site scheme formulated by Irwin (1983), and
- Long travel time scheme.

The user has the option of choosing either the P-G or the on-site algorithm (for short travel time dispersion) and specifying when the long travel time dispersion parameters are to be implemented.

Dispersion downwind of a source, as characterized by the P-G scheme, is a function of stability class and downwind distance. Stability categories are commonly specified in terms of wind speed and solar radiation. The on-site dispersion algorithm is a synthesis of Draxler's (1976) and Cramer's (1976) ideas and requires specification of the variances of the vertical and lateral wind directions. The third dispersion scheme is used in conjunction with the other two and is for long travel times in which the growth of the puff is proportional to the square root of time.

SECTION 5

TECHNICAL DESCRIPTION

This section presents the mathematical formulation of the Gaussian-puff model.

GAUSSIAN PUFF EQUATIONS

The concentration, C, of a pollutant at x, y, z from an instantaneous puff release with an effective emission height, H, is given by the following equation:

$$C(x,y,z,H) = \frac{Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{x-ut}{\sigma_x}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \left\{\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]\right\} \quad (1)$$

Since each puff is free to move in response to changing wind speed, u, and is not constrained to a single centerline, the diffusion parameters are given as functions of travel time, t, rather than of downwind distance.

Following the puff and assuming σ_x equals σ_y, expressed as σ_r, where $r = \sqrt{(x-ut)^2 + y^2}$, the puff equation can be rewritten as follows:

$$C(r,z,H) = \frac{Q}{(2\pi)^{3/2}\sigma_r^2\sigma_z} \exp\left[-\frac{1}{2}\left(\frac{r}{\sigma_r}\right)^2\right] \left\{\exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right]\right\} \quad (2)$$

When σ_z becomes larger than eight tenths of the mixed depth layer, L, the puff is assumed to be well mixed and the concentration equation is expressed as,

$$C(r,z,H) = \frac{Q}{2\pi\sigma_r^2 L} \exp\left[-\frac{1}{2}\left(\frac{r}{\sigma_r}\right)^2\right] \qquad \text{for } \sigma_z > 0.8L. \quad (3)$$

The total contribution from all the puffs is summed at each receptor after each time step.

Although a Gaussian-puff model, such as INPUFF, is useful in estimating pollution dispersion under unsteady and nonuniform flow, it has several limitations:

(1) Pollution dispersion within the puff is assumed to be Gaussian and meteorological conditions within a time step are assumed to be spatially and temporally uniform. These assumptions may cause significant error in estimating concentrations, especially at long travel distances.

(2) The diffused material is assumed to be stable and to remain suspended in the atmosphere over a long period of time. Chemical reactions, atmospheric removal, and other nonlinear processes are not handled by INPUFF.

(3) Data for puff diffusion is sparse and there is no ordering of the σ curves by stability; therefore, many Gaussian-puff models use plume σ's. However, similarity theory for puff diffusion (Batchelor, 1952) suggests that there is a region in which puff growth is greater than plume growth. For downwind distances where travel time is larger than sampling time, the use of plume σ's in a puff model may be inappropriate. However, as long as the variations in meteorological conditions are not simulated to any finer resolution than 3 to 10 minute periods, the use of plume characterizations of dispersion may still be reasonable.

(4) As mentioned, the primary purpose of the integrated puff model is to simulate a continuous plume. Plume diffusion formulas apply to continuous plumes, where the sampling time is long compared to the travel time from source to receptor. Since INPUFF uses the plume characteristics of σ_y and σ_z, one would expect that the concentration estimates from INPUFF would yield the best agreement with observations if the travel time was short compared to the sample duration of the concentration estimates. Since this assumption is violated, the model estimates relate more to the average of many realizations of the same experiment, recognizing that the correspondence of any one experiment may differ greatly in comparison to the average obtained from many experiments.

(5) Given the complex nature of the wind field, sampling the flow so that it can be completely defined from a mathematical point of view is impossible. There can always be any number of solutions which could stem from one initial state, while satisfying all other requirements.

The most important difference between Gaussian-plume models and INPUFF is that INPUFF can handle changing meteorological conditions, whereas typical Gaussian-plume models assume spatial and temporal uniformity in the meteorology.

INPUFF is similar to grid models in that both require the construction of a spatial and temporal wind field. Grid models, which solve the diffusion equation via finite-differencing schemes, are of an Eulerian type, whereas INPUFF is of a Lagrangian type. Grid models can incorporate nonlinear processes, such as chemical reactions. However, they require more computer processing time. Another problem with grid models is that because of computer memory limitations, the grid spacing is usually too large to incorporate physical processes such as plume rise and stack downwash.

PLUME RISE

Plume rise from point sources is calculated using the methods of Briggs (1969, 1971, 1973, and 1975). These equations are based on the assumption that plume rise depends on the inverse of the mean wind speed and is directly proportional to the two-thirds power of the downwind distance from the source, with different equations specified for neutral or unstable conditions and for stable conditions. Only the final rise equations are summarized below. The reader is referred to Appendix A for the details of the formulation.

For unstable or neutral atmospheric conditions, the downwind distance of final plume rise is

$$x_f = 3.5x^*,$$

where

$$x^* = 14F^{5/8} \qquad \text{for } F < 55 \text{ m}^4/\text{sec}^3$$

and

$$x^* = 34F^{2/5} \qquad \text{for } F \geq 55 \text{ m}^4/\text{sec}^3.$$

The final plume rise under these conditions is

$$H = h' + [1.6F^{1/3}(3.5x^*)^{2/3}/u(h)]. \qquad (4)$$

For stable atmospheric conditions, the downwind distance of final plume rise is

$$x_f = 0.0020715u(h)s^{-1/2}$$

where

$$s = g(\partial\theta/\partial z)/T.$$

Plume rise is

$$H = h' + 2.6\{F/[u(h)s]\}^{1/3} \qquad \text{for windy conditions} \qquad (5)$$

and

$$H = h' + 4F^{1/4}s^{-3/8} \quad \text{for near-calm conditions.} \quad (6)$$

The lower of the two values obtained from the above two equations (5 and 6) is taken as the final effective height. Definitions and units of variables mentioned in this section are summarized in Table 2.

TABLE 2. DEFINITION OF VARIABLES USED IN PLUME RISE EQUATIONS

Symbol	Definition	Units
F	Buoyancy flux parameter	m^4/sec^3
g	Acceleration due to gravity	m/sec^2
H	Effective height of plume	m
h'	Stack height adjusted for stack downwash	m
s	Stability parameter	sec^{-2}
T	Ambient air temperature	K
u(h)	Wind speed at stack top	m/sec
x_f	Distance to final rise	m
x^*	Distance at which atmospheric turbulence begins to dominate entrainment	m

DISPERSION ALGORITHMS

The primary purpose of the integrated puff model is to simulate a continuous or semi-continuous plume for varying meteorological conditions. The vertical and lateral dispersion parameters for continuous plume dispersion models are used in INPUFF. Under steady meteorological conditions, the output concentrations of INPUFF should, all other factors such as plume rise being equal, approximate the results calculated by a Gaussian-plume model such as PTPLU. To demonstrate this, concentration estimates of INPUFF and a modified version of PTPLU† are compared. The meteorology used in this comparison is as follows:

- Wind speed -- 3 m/sec,
- Wind direction -- 270°,
- Mixing height -- 1500 m, and
- Stability class -- C.

---

† PTPLU modified to output concentrations at various downwind distances instead of maximum concentration and distance to the maximum.

INPUFF was executed for a 2-hour simulation to bring about steady-state conditions.

Table 3 summarizes the results. The last column shows the percent difference in the computed concentrations for the two models. Although they differ by a factor of five at receptors close to the source, the percent difference decreases to less than 5% near the maximum concentrations. The results show that INPUFF can indeed simulate a continuous plume.

TABLE 3. COMPARISON OF INPUFF AND PTPLU

Downwind distance (km)	Concentration ($\mu g/m^3$)		Difference †
	INPUFF	PTPLU	(%)
2.154	0.20	0.04	400.00
2.448	1.06	0.44	140.91
2.783	4.27	2.60	64.23
3.162	13.19	10.12	30.34
3.594	32.41	28.24	14.77
4.084	65.07	60.62	7.34
4.642	108.50	105.75	2.60
5.275	158.00	156.52	0.95
5.995	202.90	203.42	- 0.26
6.813	233.30	238.55	- 2.20
7.743	252.10	257.88	- 2.24
8.799	254.80	261.42	- 2.53
10.000	245.30	251.87	- 2.61
11.365	224.80	233.15	- 3.58
12.915	197.30	209.25	- 5.71

† Difference(%) = [(INPUFF - PTPLU)/PTPLU] 100

Three dispersion algorithms are incorporated within the model to account for initial dispersion, short travel time dispersion, and long travel time dispersion. The initial dispersion algorithm handles the finite size of the release through the use of initial dispersion parameters. Once the puff leaves the source its growth is determined by the short travel time dispersion algorithm. This algorithm has two schemes: the Pasquill-Gifford scheme which characterizes dispersion as a function of downwind distance and the on-site scheme which characterizes dispersion as a function of travel time. For long travel time, a dispersion algorithm that allows the puff to grow as a function of the square root of time is used.

Initial Dispersion

The initial dispersion of the plume at the source is modeled by specifying the initial horizontal and vertical dispersion parameters, σ_{ro} and σ_{zo}. For tall stacks these parameters, generally, have little influence on downwind concentrations. However, if the source is large enough or close enough to the ground, then initial size is important in determining ground level concentrations near the source. For a source near the ground, the initial horizontal dispersion can be calculated by dividing the initial horizontal dimension of the source by 4.3, and the initial vertical dispersion parameter is derived by dividing the initial height of the source by 2.15. This method of accounting for the initial size of near ground level release gives reasonable concentration estimates at downwind distances greater than about five times the initial horizontal dimension of the source.

Short Travel Time Dispersion

Dispersion downwind of the source can be characterized by the P-G scheme, which is a function of stability class and downwind distance, or by the on-site scheme, which is a function of travel time.

Pasquill-Gifford Scheme

The P-G values that appear as graphs in Turner (1970) are used in the model. However, for neutral atmospheric conditions two dispersion curves as suggested by Pasquill (1961) are incorporated into the model. Dispersion curves D1 and D2 are appropriate for adiabatic and subadiabatic conditions, respectively. The D2 curve is used in Turner (1970) for neutral conditions. From a practical point of view, since temperature soundings may not be available we refer to the D1 and D2 curves as D-day and D-night. P-G stability classes are numerical inputs to the puff model. Stability classes A through D-day are specified by 1-4, and classes D-night through F are specified by 5-7, respectively.

On-site Meteorology Scheme

The σ-curves of the P-G scheme above are based on data of near-ground level releases and short-range dispersion studies. These data are used to extrapolate the P-G curves to high release heights and far receptor distances. In view of this, INPUFF has an option of using on-site meteorological data to estimate dispersion. This scheme is a result of the recommendations of the American Meteorological Society's workshop on stability classification schemes and sigma curves (Hanna et al., 1977). Irwin (1983) proposed characterizing σ_y and σ_z in a manner similar to Cramer (1976) and Draxler (1976). The standard deviation of the crosswind concentration distribution, σ_y, is

$$\sigma_y = \sigma_v t f_y, \tag{7}$$

where σ_v is the standard deviation of the horizontal crosswind component of the wind, t is the downstream travel time of the pollutant, and f_y is a nondimensional function of travel time. The standard deviation of the vertical concentration distribution, σ_z, for an elevated source, when σ_z is less than the source height, is

$$\sigma_z = \sigma_w t f_z, \tag{8}$$

where σ_w is the standard deviation of the vertical component of the wind, and f_z is a nondimensional function, primarily dependent upon travel time. The nondimensional functions f_y and f_z were characterized by Irwin (1983) as

$$f_y = 1./[1 + 0.9(t/1000)^{1/2}], \tag{9}$$

$$f_z = 1, \qquad \text{for unstable conditions}$$

and

$$f_z = 1./[1 + 0.9(t/50)^{1/2}] \quad \text{for stable conditions.} \tag{10}$$

Besides the P-G stability class, the scheme requires σ_v and σ_w, which are assumed to be typical of conditions at final plume height. For small angles, $\sigma_v = \sigma_a u$ and $\sigma_w = \sigma_e u$ where u is the wind speed at measurement height and σ_a and σ_e are the standard deviations of the horizontal and vertical wind angle, respectively. The puff model requires σ_a and σ_e as data input and computes σ_v and σ_w.

Long Travel Time Dispersion

That the dispersion parameters used in INPUFF satisfy the diffusion theory developed by Taylor (1921) is desirable. Taylor showed that for an ensemble average of particle displacements during stationary and homogeneous conditions, the dispersion parameters can be written as,

$$\sigma_{y,z}^2 = 2\overline{(vw)'^2}\int_0^{T_d}\int_0^t R(\tau)\,d\tau\,dt, \tag{11}$$

where $R(\tau)$ is the Lagrangian autocorrelation of the appropriate component of the wind velocity fluctuation; $\overline{(vw)'^2}$ are the variances of the lateral or vertical components of the wind velocity, respectively; and T_d is the diffusion time. For horizontal and vertical diffusions, $\overline{v'^2}$ and $\overline{w'^2}$ are used respectively instead of $\overline{(v'w')^2}$. The autocorrection starts at 1 and approaches 0 for large diffusion time. Therefore, from

Eq. 11, while the growth of the puff is linear with time near the source, the growth becomes proportional to the square root of time at large distances. In the model, after the puff has attained a specified horizontal dimension, the algorithm automatically goes to a long travel time growth rate proportional to the square root of time. The size of the puff at that time is specified by the user. For example, the user may decide that when σ_r for the puff is greater than 1000 meters the long travel time dispersion parameters should by utilized. A very large SYMAX value (see page 45) results in the long travel time code not being executed.

MIXING HEIGHT

Depending on the stack height, plume rise, and height of the mixing layer, the puffs can be above or below the mixed depth layer, L. If the puffs are above L then there are two cases that govern their growth. Initially the puffs are allowed to grow according to the P-G F curve, or if the on-site scheme is used, the puffs are restricted to a vertical growth rate characterized by σ_w = 0.01 m/sec. After the puffs attain a given size of σ_r (not actual puff size) specified by the user, the growth rate is specified by the $\sqrt{t}$.

When the puffs are below L, then there are four cases that must be considered. Cases one and two are puffs which are not well mixed vertically and whose growth rates are characterized by the short travel time sigmas or by $\sqrt{t}$. Cases three and four are puffs that are well mixed vertically and whose growth for σ_r is for short travel times or according to $\sqrt{t}$. During the modeling simulation, every puff is given a key to indicate whether it is above or below L and whether its growth rate is characterized by the short travel time sigmas or by $\sqrt{t}$.

In the modeling design, puffs are allowed to change their dispersion keys. When the height of L becomes greater than the puff height, the puffs are allowed to grow at the rate characterized by surface measurements. Normally this is a neutral or unstable situation. This transition period is likely to occur in the morning hours. In the afternoon, despite the decay of active mixing, a puff remains well mixed through the maximum mixing lid as shown in Figure 2. The maximum height of L is stored for each puff and is never allowed to decrease. This method assures that concentration does not increase with downwind distance or travel time, so as to violate the second law of thermodynamics.

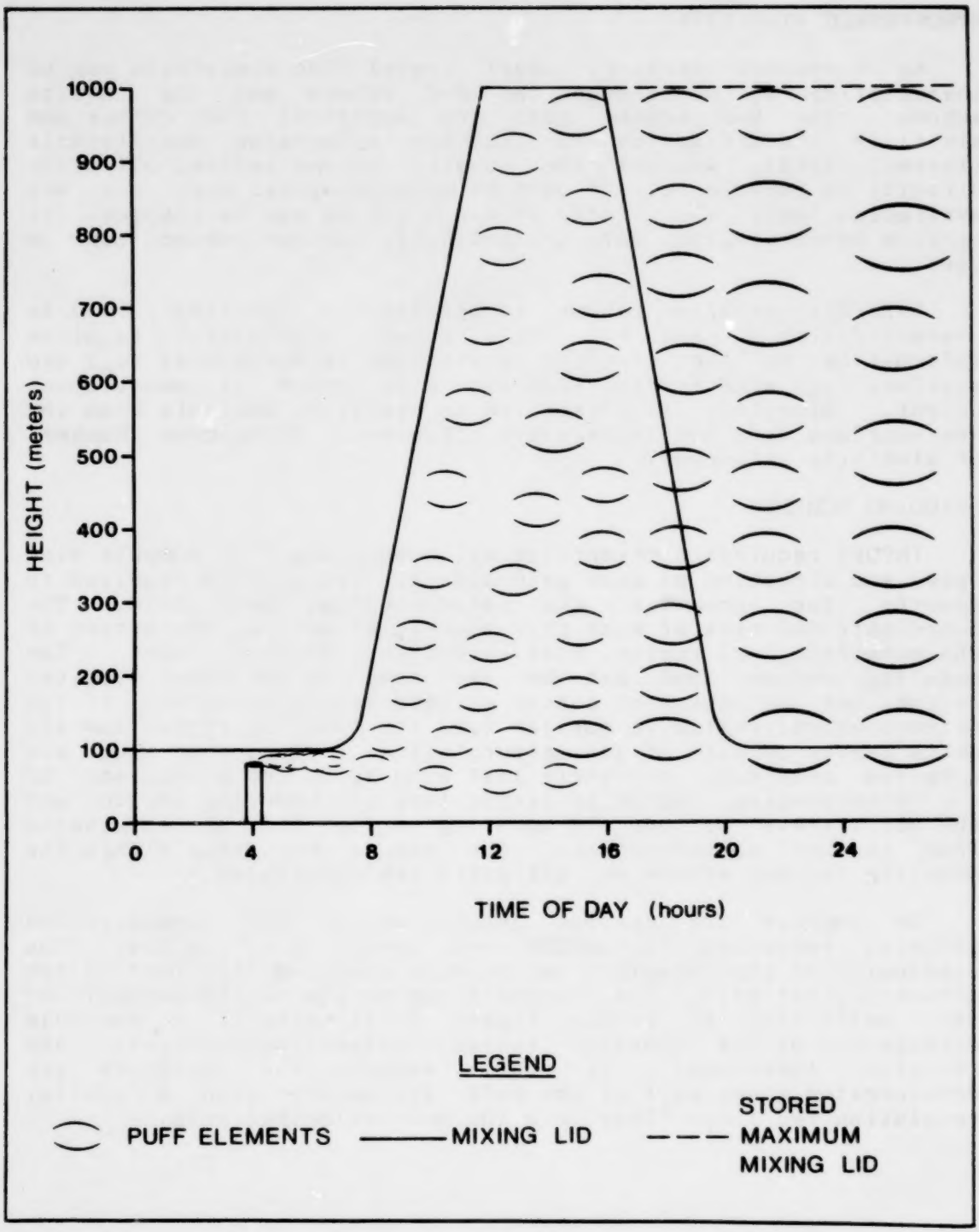


Figure 2. Effect of variable mixing height on puff dispersion.

ATMOSPHERIC STABILITY

As discussed earlier, short travel time dispersion can be characterized by two schemes, the P-G scheme and the on-site scheme. The P-G scheme uses the empirical P-G curves and stability classification to estimate dispersion coefficients (Turner, 1970), whereas the on-site scheme relates diffusion directly to turbulence. If on-site meteorological data are not available, only the widely used P-G scheme can be adopted. If on-site meteorological data are available, either scheme can be used.

INPUFF's on-site scheme adopts Irwin's algorithm (1983) in characterizing σ_y and σ_z. This scheme essentially requires information on the standard deviations of horizontal (σ_a) and vertical (σ_e) wind fluctuations and wind speed at measurement height. Stability is classified as stable or unstable from the near-surface data for temperature difference, Richardson Number, or stability parameter.

GRIDDING SCHEMES

INPUFF requires a meteorological preprocessor to compute wind speed and direction at each grid square. The user is required to specify the format of the meteorological data file. The coordinate and size of each grid square, as well as the extent of the meteorological region, must be defined in the input. The modeling region need not be the same as the meteorological region, but the southwest corner of both should coincide. If the meteorological region is smaller than the modeling region and the puffs travel outside of the meteorological region, then they are advected according to their last wind speed and direction. If the meteorological region is larger than the modeling region and the puffs travel outside the modeling region, they are eliminated from further consideration. The source must stay within the modeling region; otherwise, all puffs are eliminated.

To improve the spatial resolution of the concentration pattern, receptors in INPUFF are specified by the user. The resolution of the receptors can be more detailed than that of the meteorological grid. The receptors may be placed independent of the meteorological grid. Figure 3 illustrates a possible arrangement of the modeling region, meteorological grid, and receptor locations. In this example the receptors are concentrated along part of the puff trajectory with a spatial resolution two times finer than the meteorological grid.

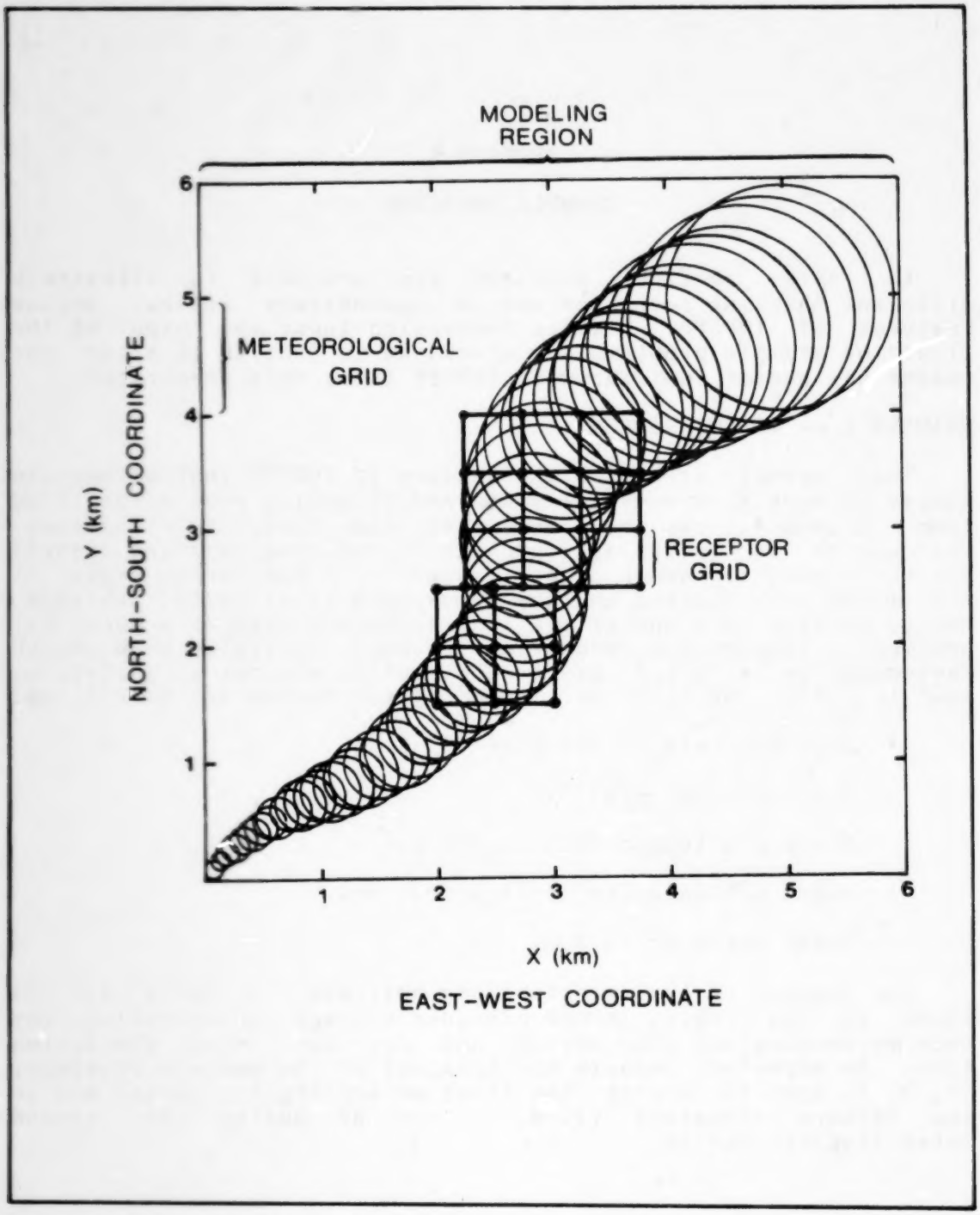


Figure 3. A possible arrangement of modeling and receptor grids.

SECTION 6

EXAMPLE PROBLEMS

In this section, problems are provided to illustrate different modeling scenarios and to demonstrate several unique features of INPUFF. Details concerning input and output of the first two example problems are discussed in Section 11 after the reader has become familiar with INPUFF input data preparation.

EXAMPLE 1 -- MOVING SOURCE

This example uses a unique feature of INPUFF that allows the source to move at a constant speed and direction over a specified time. Figure 4 shows the source path and receptor locations. The source is initially southwest of the receptors and travels due east remaining south of all receptors. Southerly winds at 3.5 m/sec are observed and the atmosphere is slightly unstable. Twenty minutes into the simulation the source assumes a northeast heading. Atmospheric conditions become neutral, wind speed increases to 4 m/sec, and wind direction changes slightly from 180° to 170°. The stack parameters of the source are as follows:

- Emission rate -- 600 g/sec,
- Stack height -- 30 m,
- Stack gas temperature -- 390 K,
- Stack gas velocity -- 15 m/sec, and
- Stack diameter -- 2 m.

The impacts at the receptors are outlined in Table 4. As shown in the table, INPUFF provides average concentrations for each meteorological time period and for the total simulation time. As expected, impacts are greatest at the western receptors (1, 2, 5, and 6) during the first meteorological period and to the eastern receptors (3, 4, 7, and 8) during the second meteorological period.

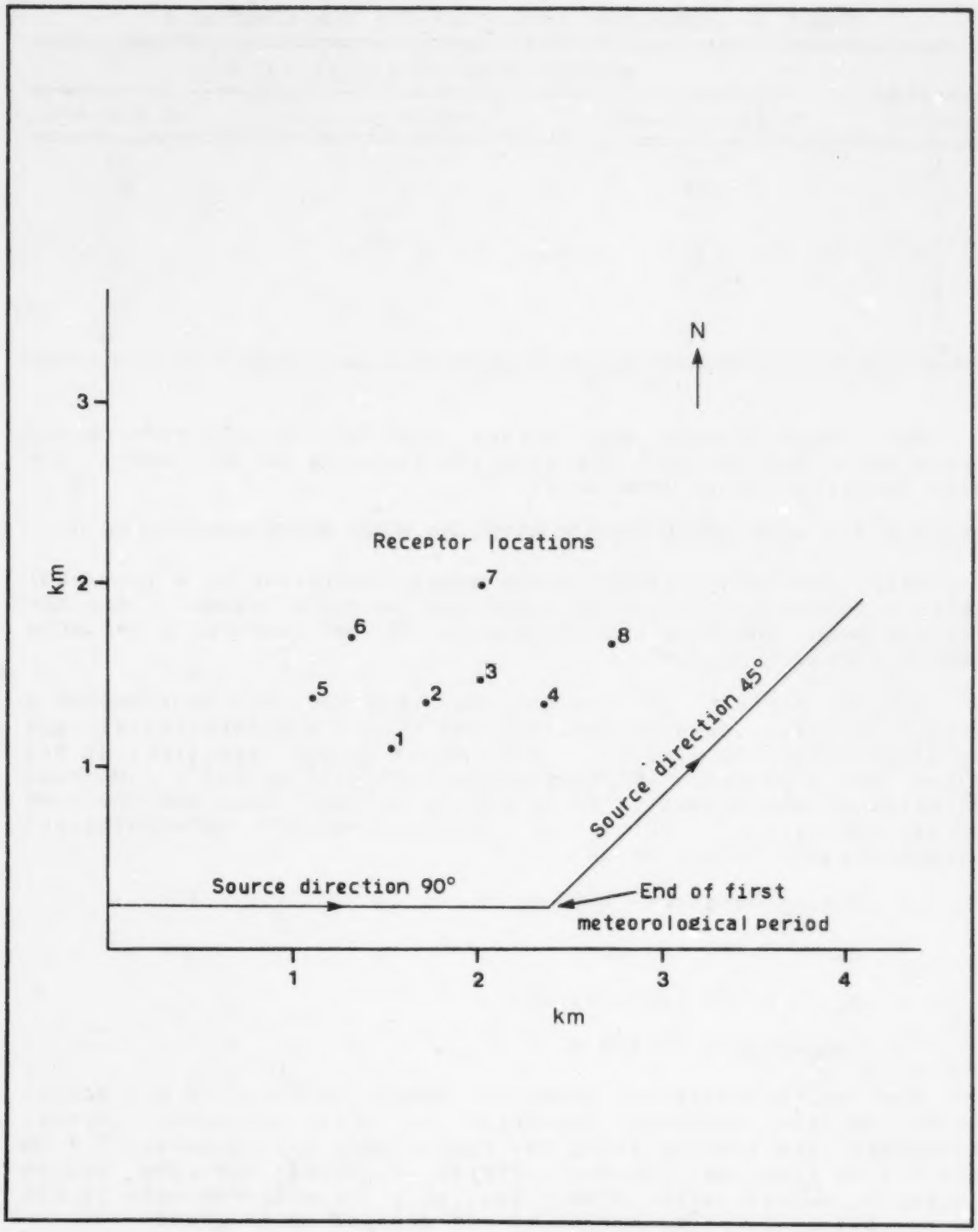


Figure 4. Source path for example 1.

TABLE 4. COMPUTED CONCENTRATIONS FOR EXAMPLE 1

Receptor number	Ambient concentrations ($\mu g/m^3$)		
	0-20 min. ave.	20-40 min. ave.	40 min ave.
1	135	<1	68
2	167	8	87
3	22	123	72
4	<1	13	7
5	181	<1	90
6	221	2	111
7	4	180	92
8	<1	13	6

The input stream and output listing for this problem are provided in Section 11. The plotting features of the model are also demonstrated in Section 11.

EXAMPLE 2 -- LOW LEVEL SOURCE WITH LOW WIND SPEED CONDITIONS

This problem illustrates the model simulation of a low level release during conditions of light and variable winds. Another feature highlighted in the problem is that of temporally variable source characteristics.

Twelve periods of 10-minute duration are used to simulate a 2-hour release. Both meteorology and source characteristics are updated every 10 minutes. The wind speeds are light at 0.5 m/sec, and wind direction fluctuates from 145° to 210°. On-site dispersion measurements of σ_a and σ_e are available and are used in the simulation. Values of other pertinent meteorological parameters are listed below:

- Mixing height -- 5000 m,
- σ_a -- 0.393 radians,
- σ_e -- 0.035 radians, and
- Temperature -- 290 K.

The source-receptor geometry shown in Figure 5 was chosen based on the observed southeast to south-southwest winds. Receptors are located along two radial arcs approximately 0.5 km and 1.0 km from the source. Figure 6 shows how the source strength decays with time. Initially the emission rate is 825 g/sec, but by the 12th period it has dropped to 12 g/sec.

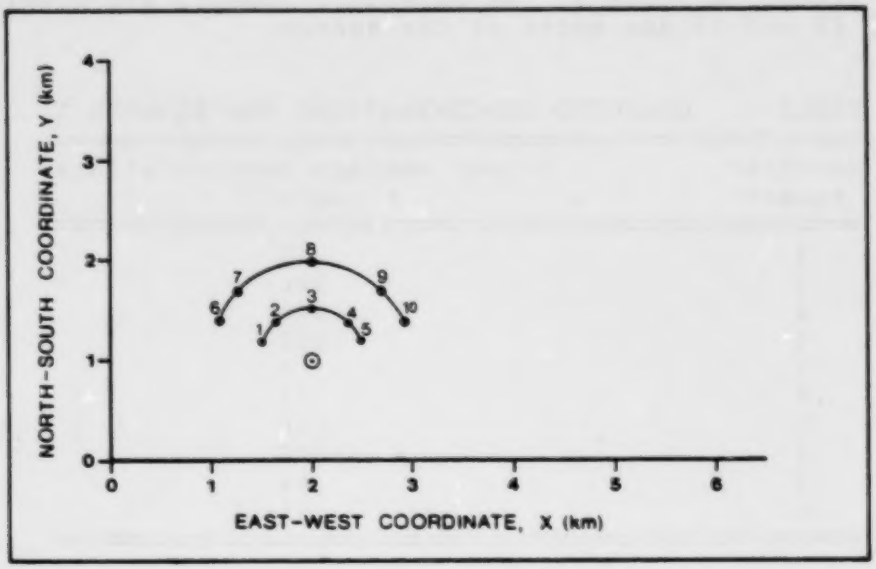


Figure 5. Source-receptor geometry for example 2.

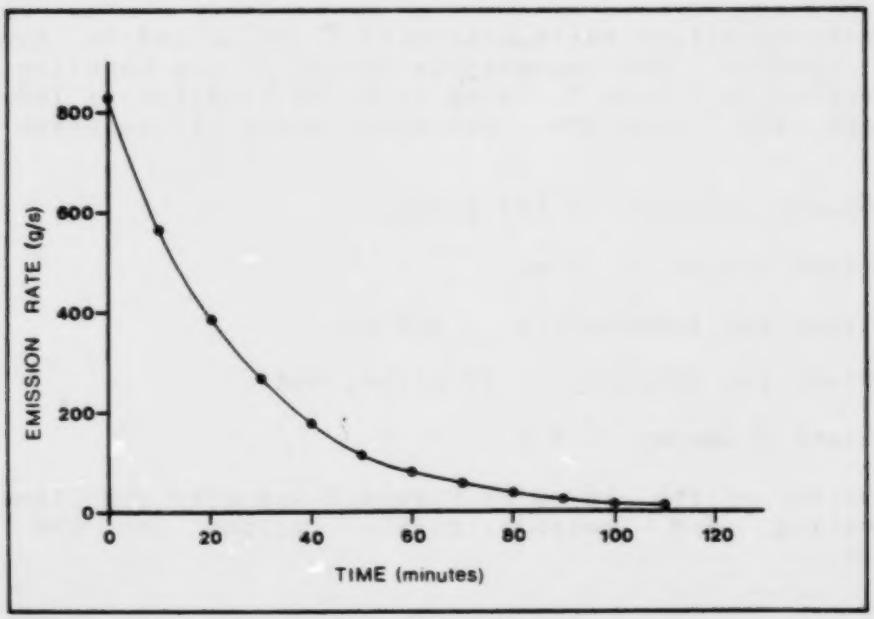


Figure 6. Emission rate versus time plot for example 2.

Average concentrations at each receptor for the simulation time are listed in Table 5. As expected, impacts are greatest at receptors (3 and 8) due north of the source.

TABLE 5. COMPUTED CONCENTRATIONS FOR EXAMPLE 2

Receptor number	2-hour average concentrations ($\mu g/m^3$)
1	13
2	536
3	4846
4	323
5	4
6	<1
7	180
8	16300
9	44
10	<1

The input stream and abridged output listing for this problem are provided in Section 11. The plotting features of the model are also shown there.

EXAMPLE 3 -- VARIABLE WIND FIELD

The user-specified horizontal wind field option is exercised in this example. The topographic relief of the modeling region is illustrated in Figure 7, along with the location of the point source and the receptors. Characteristics of the stack are as follows:

- Source strength -- 700 g/sec,
- Stack height -- 75 m,
- Stack gas temperature -- 455 K,
- Stack gas velocity -- 16 m/sec, and
- Stack diameter -- 3 m.

The boundaries of the region in Figure 7 are also the limits of the modeling and meteorological regions for the INPUFF simulation.

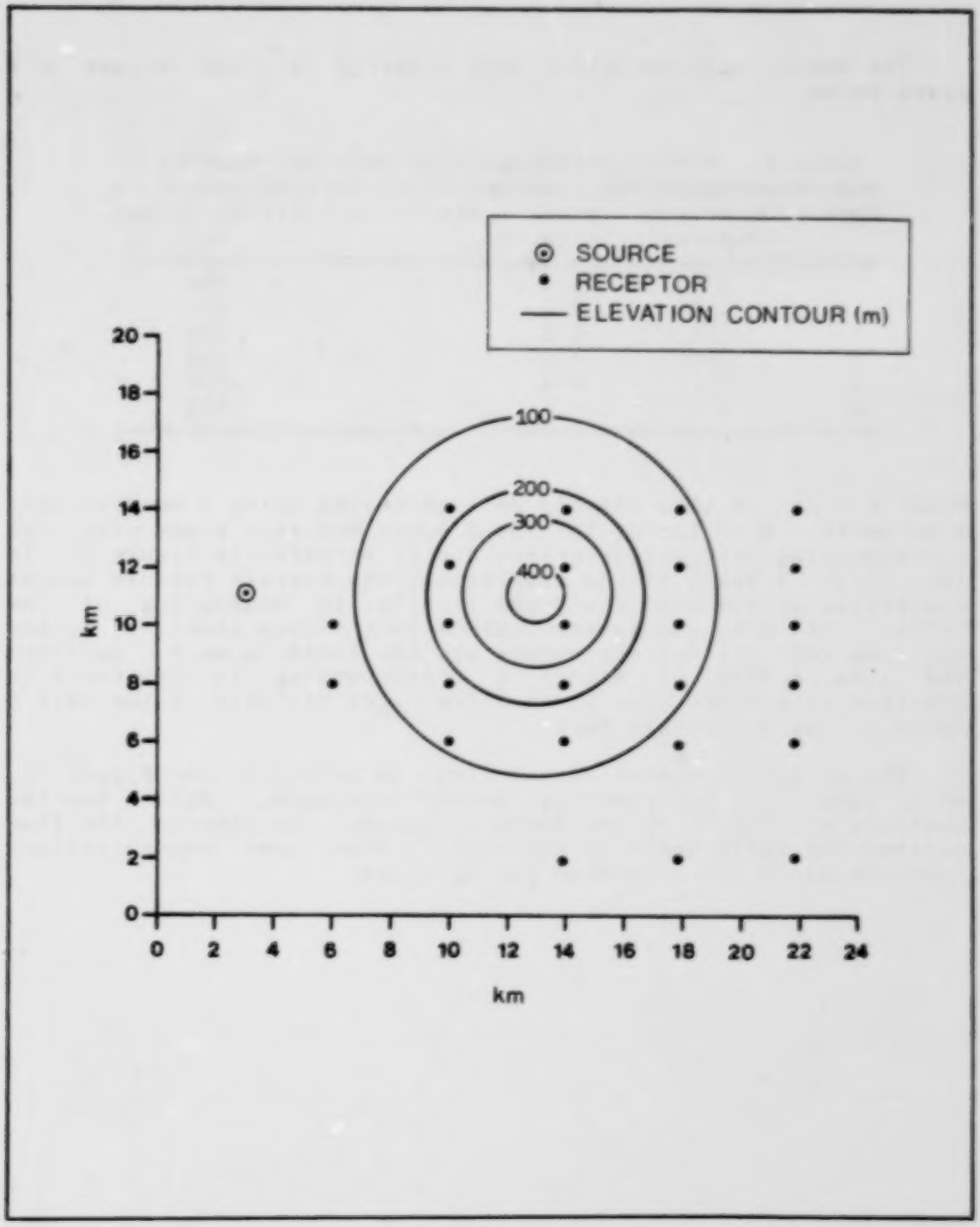


Figure 7. Topographic relief of the modeling region in example 3.

The hourly meteorological data observed at the source are given below.

TABLE 6. HOURLY METEOROLOGICAL DATA FOR EXAMPLE 3

Hour	Direction (degrees)	Speed (m/sec)	Stability	Mixing Height (m)
1	272	2.4	F	200
2	265	2.4	F	200
3	272	2.6	E	200
4	282	4.0	D, day	400
5	298	4.9	C	1000
6	315	6.0	C	1500

Wind fields in this example were generated using a nondivergent wind model. Wind fields for the 6 hours modeled, along with the corresponding puff trajectories, are illustrated in Figure 8. In the first 3 hours of the simulation, the terrain feature causes distortion of the wind field and results in meandering of the puffs. As the atmosphere becomes less stable (hours 4, 5, and 6), flow over the terrain occurs and the field is more uniform. The wind fields of Figure 8 corresponding to the hours in question illustrate this point. The puffs released in the last 3 hours follow a straight path.

The pollutant concentration field is provided in Figure 9, with isopleths representing 6-hour averages. Notice how the contours are "bent" by the terrain feature. In general, the flow carried the puffs south of the peak. Thus peak concentrations occurred along the southward facing slope.

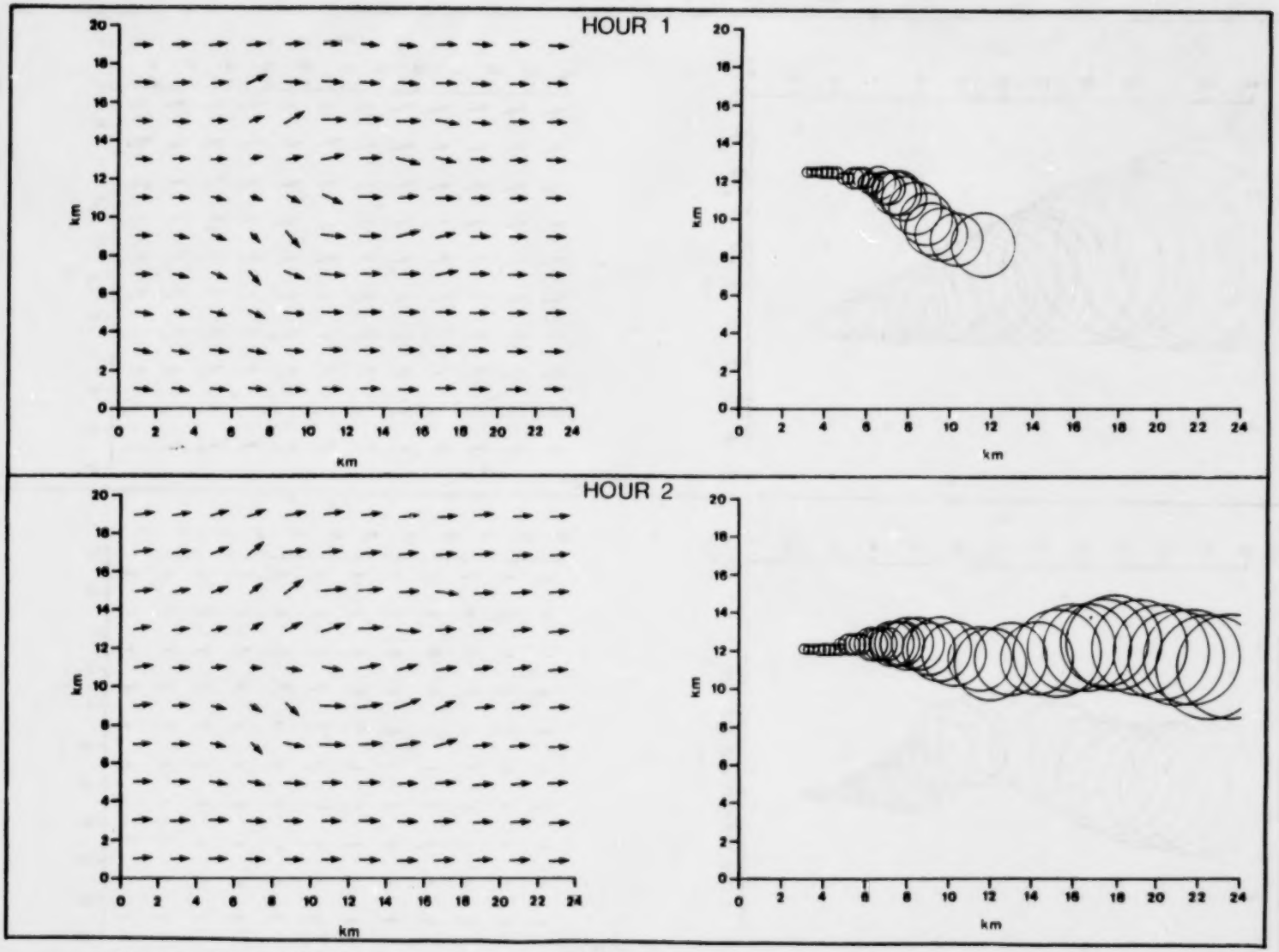


Figure 8. Wind fields and puff trajectories of each hour for example 3.

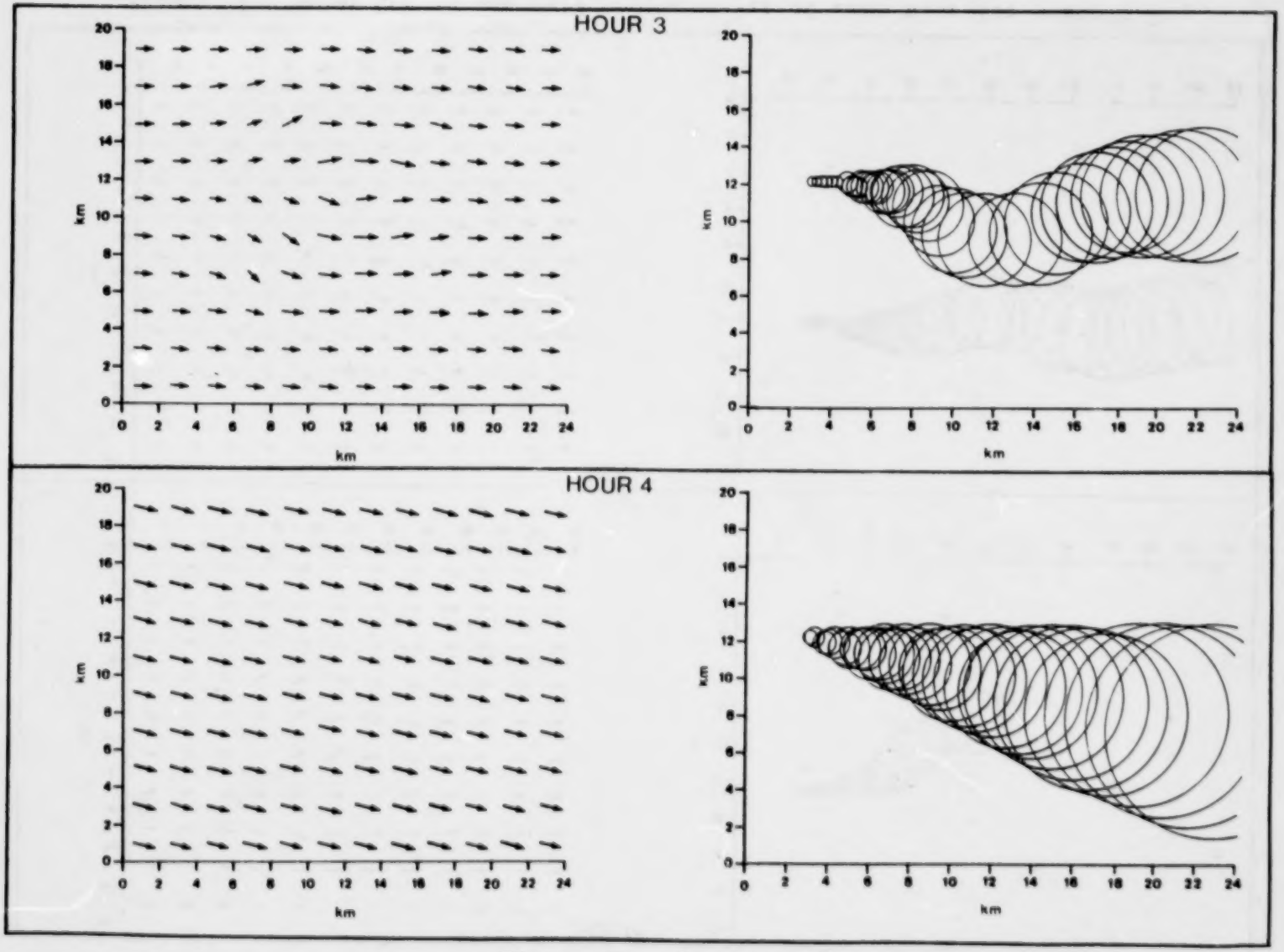


Figure 8. (continued)

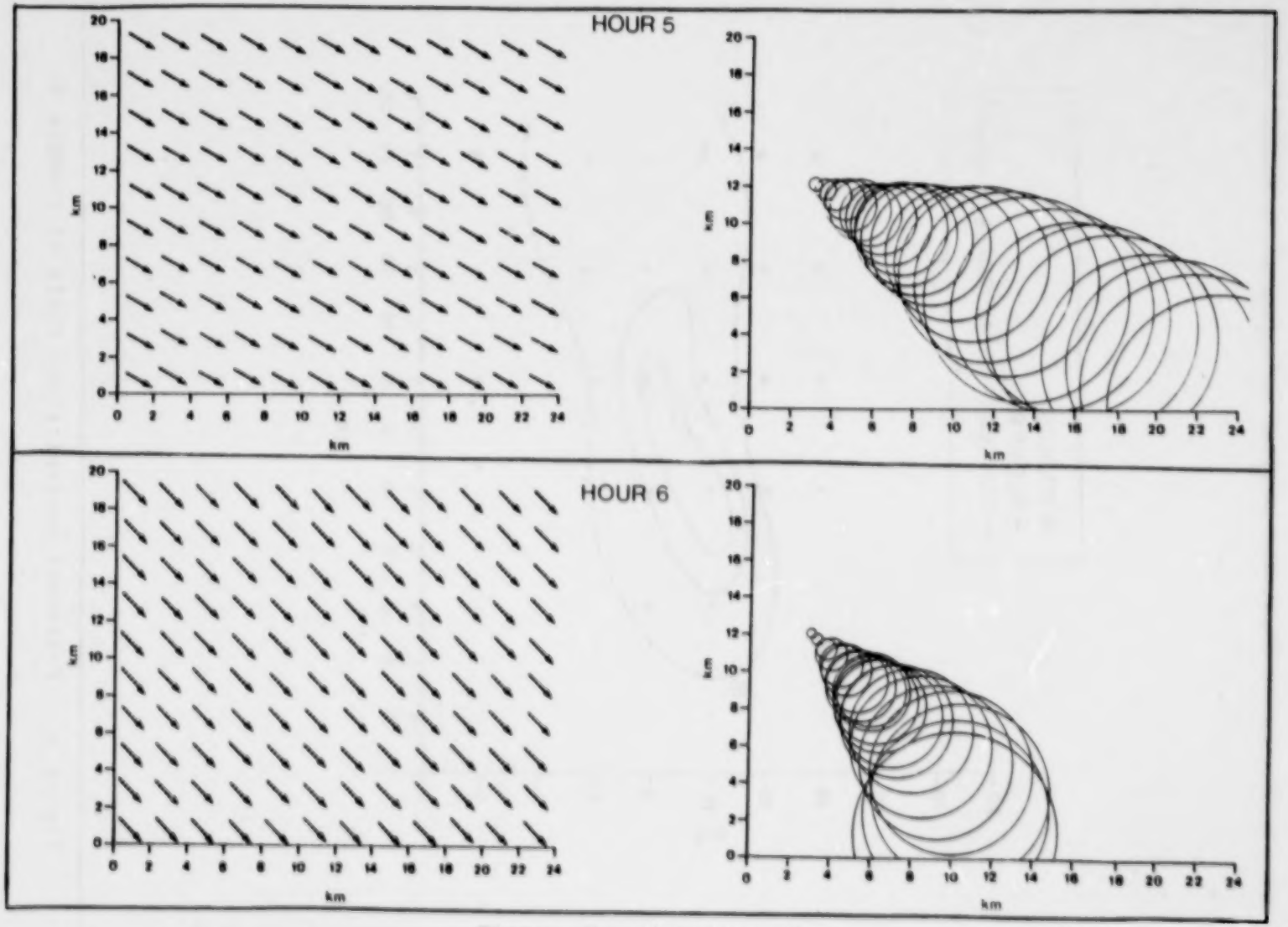


Figure 8. (continued)

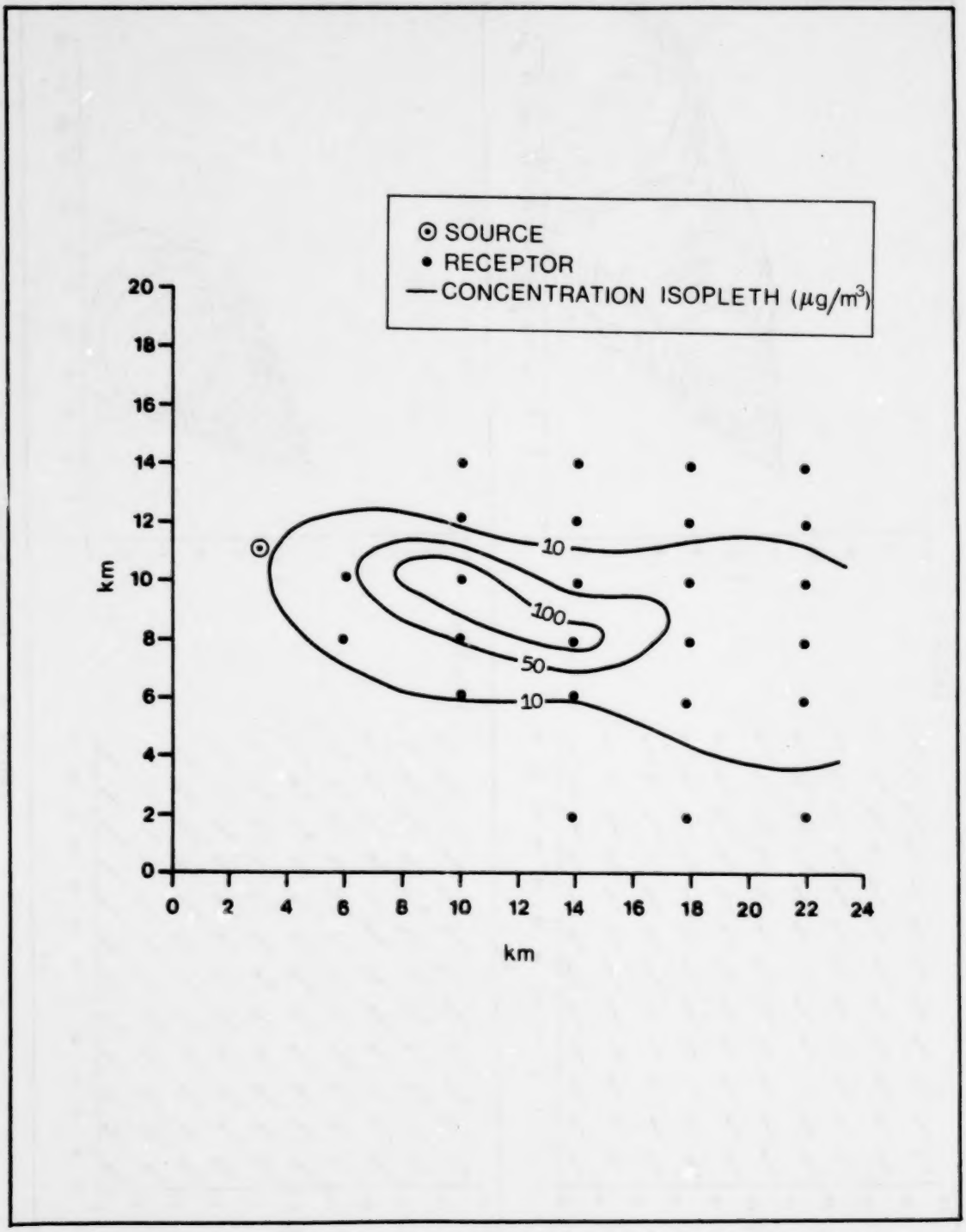


Figure 9. Pollutant concentration field of example 3.

SECTION 7

COMPUTER ASPECTS OF THE MODEL

INPUFF

This section discusses the general framework of INPUFF. The section is intended to give the reader a general knowledge of the computer program, rather than a detailed description of each subroutine. The general flow of INPUFF, the structure of the computer subroutines and functions, and a brief description of each subroutine and function are included.

The main routine reads the following types of information:

- Options to be exercised during program execution,
- Simulation information and puff characteristics,
- Specifications of the modeling region,
- Source characteristics,
- Receptor coordinates, and
- Meteorological data.

INPUFF is a single source model that permits source characteristics to be updated every meteorological period. The meteorology during the modeling exercise can be specified by up to 144 equal length meteorological periods. Concentration estimates can be made for 25 locations. If the user does not apply the wind field option, all input data are read by the main routine, which also produces all printed output.

Figure 10 shows the structure of the subroutines and functions. PUFF is the main routine that reads input data and stores the appropriate data in common with the other subroutines. A brief description of the main program, subroutines, and functions follows.

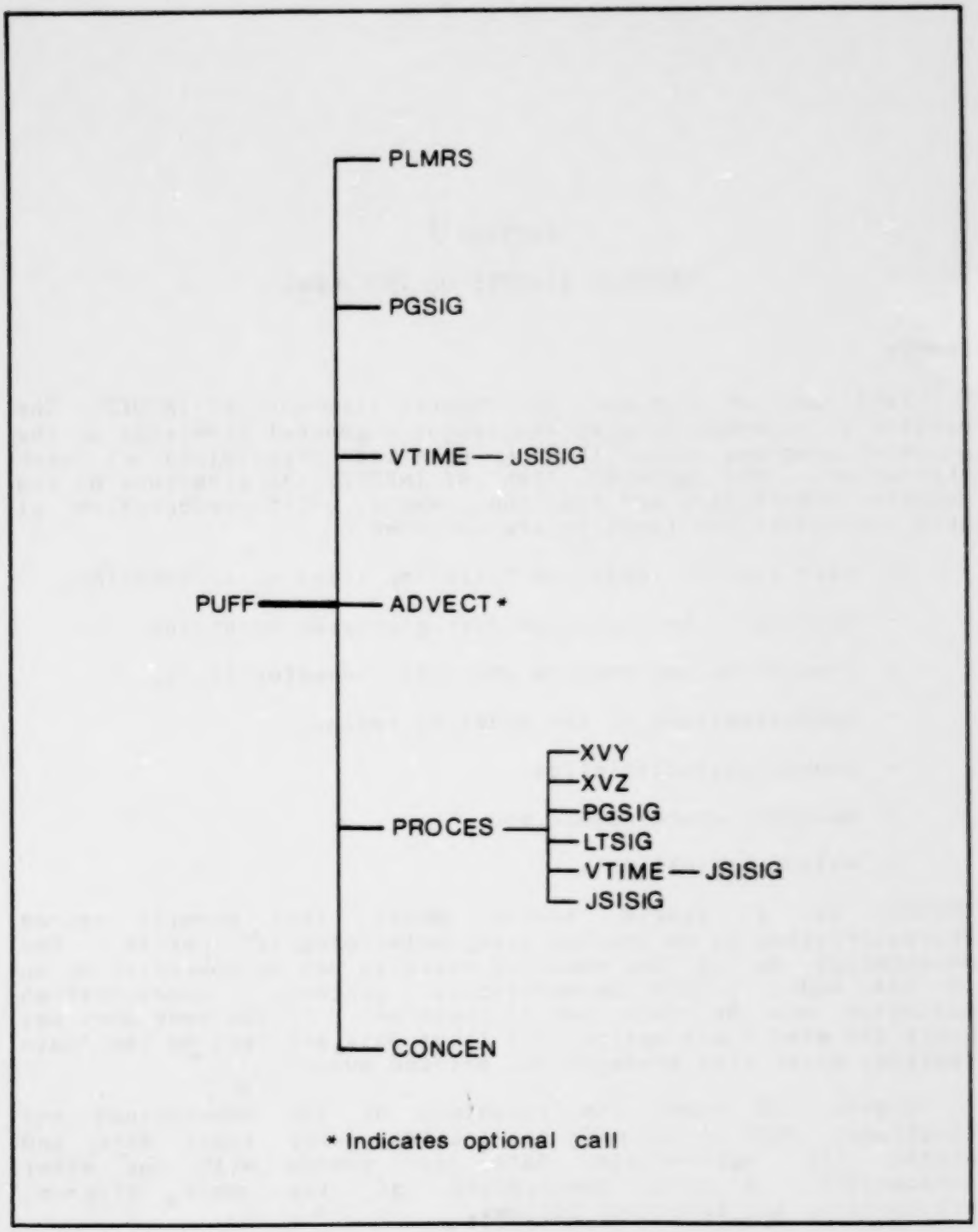


Figure 10. Structure of INPUFF.

PROGRAM MODULES

PUFF -- PUFF is the main program that reads all inputs except wind field data, if that option is to be exercised. The following subroutines are called by PUFF: PLMRS, PGSIG, VTIME, ADVECT, PROCES, and CONCEN. The main program generates the puffs, computes the initial dispersion and plume rise, advects the puffs, and combines the puffs where appropriate. PUFF prints out the input data and the concentration estimates at each receptor for each time period.

PLMRS -- This subroutine is called by PUFF and computes the plume rise based on Briggs' equations.

PGSIG -- This subroutine is called by PUFF and PROCES to compute the P-G dispersion parameters.

VTIME -- This subroutine is called by PUFF and computes the virtual time necessary to account for the current size of the puff using the on-site scheme. The process is analogous to the virtual distance concept. The only subroutine called by VTIME is JSISIG.

ADVECT -- This subroutine is called by PUFF if the user-supplied wind field option is exercised (i.e., IADT = 1). ADVECT reads the gridded wind field data from unit 21, and computes the appropriate wind speed and direction for each puff.

PROCES -- Called directly by PUFF, the major functions of PROCES are to: determine which dispersion routine is called for each puff, assign dispersion keys (KEYP) for each puff, account for the effect of the mixed depth layer for each puff, and compute σ_r and σ_z for each puff. PROCES calls subroutines PGSIG, LTSIG, VTIME, and JSISIG, and functions XVY and XVZ.

CONCEN -- This subroutine is called by PUFF and computes the concentration from each puff for each receptor location. This subroutine also combines puffs if they are within a user supplied distance (ALPHA times σ_r) of each other.

XVY -- This function is called by PROCES and calculates the virtual distance necessary to account for the initial crosswind dispersion using the P-G scheme.

XVZ -- This function is called by PROCES and calculates the virtual distance necessary to account for the initial vertical dispersion using the P-G scheme.

LTSIG -- This subroutine is called by PROCES and computes the dispersion parameters for long range transport.

JSISIG -- This subroutine is called by VTIME and PROCES and computes the dispersion parameters for short travel time transport using the on-site scheme.

Subroutines PLMRS, PGSIG, ADVECT, CONCEN, XVY, XVZ, LTSIG, and JSISIG are lowest-level subroutines, i.e., they do not call any other routine.

The table below gives the input/output units used by the model.

TABLE 7. INPUT/OUTPUT UNITS USED BY THE MODEL

Unit number	Mode	Contents
5	Input	Program control and input data
6	Output	Output listing
21	Input	User-supplied wind field
22*	Output/input	Input data for plotting software

* Output from the main routine and input for plotting routine.

PLOT POSTPROCESSOR

The plot routine reads the following types of information:

- Type of plots desired,
- Location of concentration versus time plots, and
- Plotting grid.

The above information is read from unit 5. The following information, generated by the main routine if IP22 = 1 (see Table 8), is read from unit 22:

- Number of meteorological periods,
- Length of each meteorological period,
- Total simulation time,
- Location of each receptor,
- Computed concentrations at each receptor, and
- Location of each puff and its σ_r and σ_z value.

The plot routines were developed on a UNIVAC 1110 and call CALCOMP plotting software. The main program calls two subroutines which actually do the plotting. These are PLTCON, which generates concentration versus time plots at specified receptor locations, and PLTTRJ, which plots puff trajectories and receptor locations. The input data for the plot routines are shown in Table 9 and are described in the next section.

SECTION 8

INPUT DATA PREPARATION

RECORD INPUT SEQUENCE FOR INPUFF

There are eleven record types that are read by INPUFF. Seven of these are free format input, three are alphanumeric, and one is a user-specified format. While the free format is very easy to use, care should be taken to ensure that every variable is given a value in the correct order. Each variable should be separated by a comma and should conform to the variable name type. Three of the eleven input records are optional, depending on the options exercised on record 2. A brief description of each input parameter is given in Table 8 with the appropriate units; the metric system of units is used throughout the model. Thus horizontal coordinates of source and receptor locations are in kilometers, temperatures in degrees kelvin, and emission rates in grams per second. Under the "Format" column of Table 8, AN refers to alphanumeric, FF represents free format, and US indicates user-specified format.

TABLE 8. RECORD INPUT SEQUENCE FOR INPUFF

Record type & Variable	Format	Variable description	Units
Record 1			
ALP	AN	80-character title to describe output	--
Record 2			
IOPT	FF	Stack downwash option (1 = use option, 0 = do not use)	--
IOPS	FF	Update source characteristics option (1 = source information update every meteorological period, 0 = no update)	--

(continued)

TABLE 8. (continued)

Record type & Variable	Format	Variable description	Units
IADT	FF	User-supplied wind field option (1 = use option, 0 = do not use)	--
IP22	FF	Unit 22 output option (1 = use option, 0 = do not use)	--
IPCC	FF	Print out option (1 = puff information to be printed each ITIME, 0 = no print out)	--
IPIC	FF	Print intermediate concentration option (1 = print out, 0 = no print out)	--
Record 3 -- Optional			
XSWC	FF	East-west coordinate of SW corner of wind field grid	km
YSWC	FF	North-south coordinate of SW corner of wind field grid	km
NUMX	FF	Number of grid squares in east-west direction	--
NUMY	FF	Number of grid squares in north-south direction	--
DX	FF	East-west width of grid squares	km
DY	FF	North-south width of grid squares	km
Record 4 -- Optional			
FRMAT	AN	Format of unit 21. Subroutine ADVECT reads unit 21 according to the format specified in FRMAT	--
Record 5			
NTIME	FF	Number of meteorological periods for simulation	--
ITIME	FF	Time span of each meteorological period	sec

(continued)

TABLE 8. (continued)

Record type & Variable	Format	Variable description	Units
ISTEP	FF	Time between puff release (If ISTEP < 0 a value for ISTEP will be computed based on the stability class, wind speed, and minimum distance from the source to the receptor - CDIS).	sec
INC	FF	Time interval at which concentrations are printed out. INC must be evenly divisible into ITIME.	sec
ISIM	FF	Time to start concentration calculations	sec
ISTTIM	FF	A multiple of ISTEP for puff combination	--
IW	FF	Unit number for write statements	--
DISKEY	FF	Dispersion parameter options DISKEY = 1 for P-G scheme DISKEY = 2 for on-site scheme	--
NREC	FF	Number of receptors	--
ANHGT	FF	Anemometer height	m
Record 6			
XGRID	FF	East-west coordinate of SW corner of modeling region	km
YGRID	FF	North-south coordinate of SW corner of modeling region	km
XSIZE	FF	East-west size of modeling region	km
YSIZE	FF	North-south size of modeling region	km

(continued)

TABLE 8. (continued)

Record type & Variable	Format	Variable description	Units
STANUM	FF	If the puff center is at a greater distance than the product of STANUM and σ_r from a receptor, no concentration calculation is made at that receptor for that puff.	--
ALPHA	FF	Fraction of σ_r for puff combination	--
SYMAX	FF	Maximum size of σ_r before going to LTSIG routine to calculate the dispersion parameters	m
Record 7			
XSORC	FF	East-west coordinate of the source	km
YSORC	FF	North-south coordinate of the source	km
QP	FF	Emission rate	g/sec
HPP	FF	Height of release	m
TSP	FF	Stack gas temperature	K
DP	FF	Stack diameter	m
VSP	FF	Stack gas velocity	m/sec
VFP	FF	Stack gas volume flow	m^3/sec
SYOP	FF	Initial σ_r	m
SZOP	FF	Initial σ_z	m
SDIR	FF	Source direction, if moving	deg
SSPD	FF	Source speed	m/sec
Record 8			
XREC	FF	East-west coordinate of receptor	km
YREC	FF	North-south coordinate of receptor	km

(continued)

TABLE 8. (continued)

Record type & Variable	Format	Variable description	Units
ZREC	FF	Height of receptor	m
Record 9			
FRMT	AN	Format of the meteorological data to be read on record 10 (see page 55)	--
Record 10			
WDIR	US	Wind direction	deg
WSPD	US	Wind speed	m/sec
HL	US	Mixing height	m
KST	US	Stability class (see page 45)	--
SGPH	US	Standard deviation of elevation angle, σ_e	radians
SGTH	US	Standard deviation of azimuth angle, σ_a	radians
TEMP	US	Air temperature	K
CDIS	US	Minimum distance from source to receptor	km
Record 11 -- Optional			
	FF	Record 11 is optional and is read if IOPS = 1 (record 2). If IOPS = 1 then there must be NTIME-1 number of records in this group to update source data. The description of pertinent variables is given in record type 7 beginning with QP.	--

US = User-specified format

Most of the input data are straightforward and typical of the kind of information required for Gaussian models. However, there are some input variables which are unique to this code and require additional explanation to ensure proper assignment of values.

Records 3 and 4

Records 3 and 4 are read if IADT = 1. The information on record 3 defines the coordinates of the SW corner of the gridded region and the size of each grid square. The user must define the wind speed and direction in each grid square. There are a few caveats associated with using gridded meteorological data. The source must stay within the defined region. The meteorological region defined on record 3 need not be the same as the modeling region defined on record 6, but the southwest corner of both should have the same coordinates. If the meteorological region is smaller than the modeling region and the puffs travel outside of the meteorological region, then they will be advected according to their last wind speed and direction. If the meteorological region is larger than the modeling region and the puffs travel outside the modeling region, they will be eliminated from further consideration. Record 4 requires the user to input the format of his meteorological data file. This file has to be assigned to unit 21, and is read by subroutine ADVECT according to the format specified on record 4. This is the only statement read outside of the main routine. If the option to specify the wind field is exercised, then the meteorological data read on record 10 must be appropriate for the grid square that contains the source. Record 10 must be supplied whether or not the wind field option is exercised.

Record 5

The data requested on record 5 give the program information regarding the modeling design. NTIME is the number of meteorological periods simulated in a run. ITIME is the time period associated with the meteorological data. For example, if the meteorological data are recorded in 20-minute averages and the user wants to make a 3-hour simulation, then NTIME = 9 and ITIME = 1200 seconds. ISTEP is the time interval between puff releases. If ISTEP is assigned a negative value the model computes ISTEP based on the stability class, wind speed, and minimum distance from source to receptor. The minimum value that can be assigned to ISTEP is 1 second. When assigning ISTEP for a moving source, be sure to take into account the path of the source when computing the minimum distance between source and receptor (CDIS), specified on record 10. ISTEP should always be divisible into ITIME and no greater than one-half the value of INC. INC is a time interval for which intermediate concentration values are printed out. For example, if ITIME = 1200 and INC = 300, then four 5-minute average concentration tables are printed (if IPIC = 1) as well as the 20-minute average concentration table.

The next two input parameters, ISIM and ISTTIM, are used to reduce computing time. ISIM is the time when concentration calculations are to begin. For many cases ISIM is assigned a value of zero. However, if the minimum source-receptor distance is large and requires a substantial amount of travel time for the puffs to reach the receptor, a value for ISIM can be assigned which would advect the puffs downwind but would delay the concentration calculations until the current time equaled ISIM. ISTTIM has to be an integer multiple of ISTEP. For example, if it is desired to test for puff combination every third puff release, then ISTTIM = 3. The user should not assign a value of ISTTIM such that ISTTIM * ISTEP is greater than ITIME.

Record 6

XGRID, YGRID, XSIZE, and YSIZE on record 6 are used to define the modeling region. STANUM and ALPHA are used to reduce computation time, and SYMAX is used to specify when the model should go to long travel time dispersion.

The parameter ALPHA controls when puff combinations take place. Combinations occur only for adjacent puffs in the release sequence which have the same dispersion key. A puff can have one of six possible dispersion keys: (1) puff is below the mixing height and using short travel time dispersion; (2) puff is using long travel time dispersion; (3) puff is above the mixing height; (4) puff is well mixed and using either P-G or on-site dispersion; (5) puff is above the mixing height and using long travel time dispersion; and (6) puff is well mixed and using long travel time dispersion. For instance, suppose two puffs are adjacent in time and have identical dispersion keys. If ALPHA is 1 then the puffs combine when their centers are within σ_r of each other (σ_r of the younger puff is used for the test). If ALPHA equals 2, then the puffs combine when their centers are within $2\sigma_r$ of each other. A value of ALPHA equal to 0 results in no puff combinations. ALPHA can be assigned any value; however, in practice, ALPHA equal to 1 is a reasonable value for puff combination.

Upon combining puffs, the position, displacement, and travel time are averaged between the two puffs. The mass is summed and the dispersion parameters and virtual position are that of the younger puff.

The parameter STANUM controls whether or not a concentration estimate is made for a given puff at a given receptor. STANUM is the number of σ_r's in the horizontal dimension that the puff has to be from the receptor before a concentration estimate is made for that puff. For example, if STANUM equals 5, no concentration estimate is made for any puff at a given receptor if the distance between the receptor and the puff center is greater than $5\sigma_r$.

SYMAX is the maximum size of σ_r for any puff before the program calls LTSIG to compute the dispersion parameters. SYMAX can be assigned any size (in meters) depending on how soon the user wants the model to compute the dispersion parameters as a function of the square root of time. If it is desired not to call LTSIG, then a very large value of SYMAX should be assigned.

Record 7

Source information data are specified on this record. The user should ensure that the coordinates of the source are within the modeling region. If the source is outside of the modeling region or moves outside of the modeling region, all puffs emitted after that point are eliminated from further consideration. Source direction is specified in degrees from north. A source direction of 90° means the source is heading east (180° = south; 270° = west; and 360° or 0° = north).

Record 9

The user specified format for record 10 is provided on this record. The format can be either free or formatted.

Record 10

With the exception of stability class (KST) the variables on this record are typical of many air quality models. As mentioned in Section 5, INPUFF considers seven stability categories with the inclusion of D-day and D-night. Thus stability classes A through D-day are specified by 1-4, and classes D-night through F are specified by 5-7, respectively.

INPUT DATA FOR PLOT POSTPROCESSOR

The input data for the plot postprocessor, assigned on four input records, are read using free format (indicated by an FF in Table 9). Table 9 shows the input parameters for each record with the appropriate units. The main routine of the plotting package reads the input data and the information generated on unit 22 by the main routine of the puff model. There are two plots which are optional output in the execution of the plotting routine. One is a plot of concentration versus time and the other is a plot of the puff trajectory at the end of each meteorological period. Either one or both of the plots may be requested during a given simulation.

TABLE 9. RECORD INPUT SEQUENCE FOR PLOT POSTPROCESSOR

Record type & Variable	Format	Variable description	Units
Record 1			
IPLT	FF	Plotting options: 1 = plot concentration versus time 2 = plot puff trajectory 3 = plot both	--
Record 2			
IYR	FF	Order of magnitude of concentration to be plotted on the y-axis. (Default value is 6)	--
NUMR	FF	Number of receptors for which concentration versus time is plotted	--
ITPT	FF	Number of periods for which concentration versus time is plotted. ITPT must be evenly divisible into NTIME. (If ITPT > 999, all periods are plotted together.)	--
XSI	FF	Length of x-axis	in
YSI	FF	Length of y-axis	in
Record 3			
IREC	FF	Receptor number for concentration versus time plots. (NUMR integers are read on this record.)	--
Record 4			
XMIN	FF	East-west coordinate of SW corner of plotting grid	km
YMIN	FF	North-south coordinate of SW corner of plotting grid	km
XSIZE	FF	East-west size of plotting grid	km
YSIZE	FF	North-south size of plotting grid	km
AXL	FF	Length of x-axis	in
AYL	FF	Length of y-axis	in

On record 2, NUMR is the number of receptor locations that a plot of concentration versus time is generated. The actual receptor numbers are read on record type 3. For example, if the user has made concentration estimates at ten locations and wishes to see the concentration versus time plots for receptors 1, 3, and 8, then NUMR = 3 and the array on record 3 is assigned the values 1, 3, and 8. The third parameter on record 2 is ITPT. This parameter allows the user to combine meteorological periods for the concentration versus time plots. If ITPT = 1, then a concentration versus time plot is generated each ITIME for all receptors specified on record type 3. However, for ease in observing the time variations in concentrations, the periods can be combined. For example, if NTIME = 3 and ITIME = 3600 (i.e., a 3-hour simulation) and a plot of concentration versus time is desired for the entire 3 hours, ITPT should be set to greater than 999. ITPT must be evenly divisible into NTIME, or be greater than 999.

SECTION 9

SENSITIVITY ANALYSIS

This section presents a simple analysis designed to acquaint the user with the magnitude of changes expected in pollutant concentrations and CPU time when certain model inputs are varied. The verification run presented in Section 10 was used as a basis for this analysis.

PUFF COMBINATION -- ALPHA

Integrated puff models are by their nature computationally time consuming. To minimize computational time required in the model, the puffs are combined or deleted, or in certain situations no computation is made. For instance, if a puff is not close to a receptor no computations may take place. The parameter ALPHA controls the rate of puff combinations. If the value of ALPHA is 1, then the puffs combine when their centers are within one lateral standard deviation of each other.

As noted in Figure 11, CPU time increases rapidly as ALPHA approaches zero due to increased number of puffs. Execution time for ALPHA equal to 0.2 is more than four times longer than for an ALPHA of 1. CPU time levels off for ALPHA greater than 1. Increasing ALPHA from 1 to 3 results in only a 50% reduction in execution time.

The sensitivity of concentrations to ALPHA is shown in Table 10. Varying ALPHA from 0 to 1 has little effect on concentrations, but for values of ALPHA greater than 1, computation errors greater than 10% may occur. This result, in conjunction with decreased computer costs with increasing ALPHA (see Figure 11), suggests that ALPHA equal to 1 is a reasonable value for puff combination.

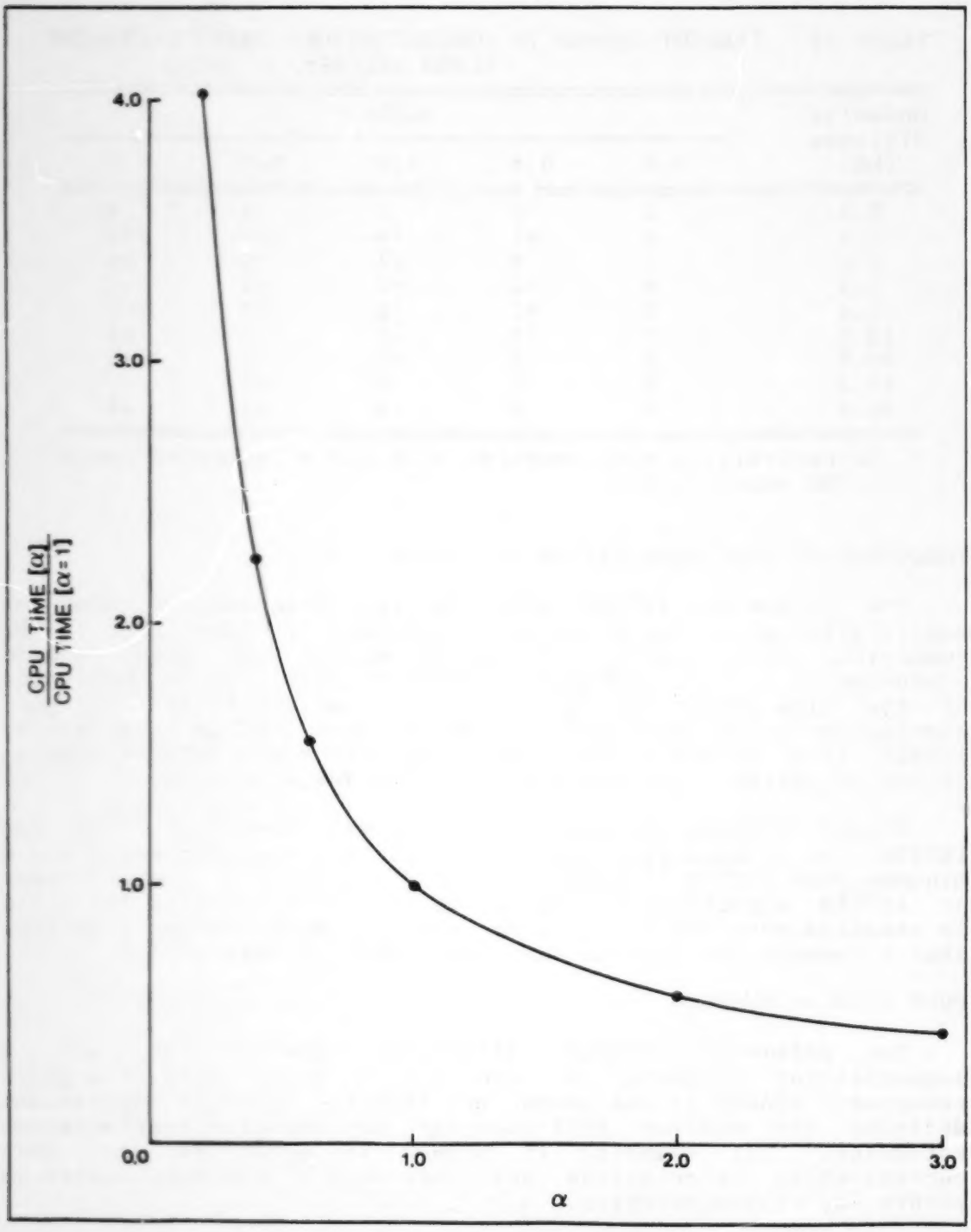


Figure 11. Sensitivity of CPU time to ALPHA.

TABLE 10. PERCENT CHANGE IN CONCENTRATIONS USING DIFFERENT ALPHA VALUES*

Downwind distance (km)	ALPHA				
	0.4	0.6	1.0	2.0	3.0
0.5	0	0	0	0	0
1.0	0	+1	+4	+10	+15
2.0	0	0	+1	+6	+9
3.0	0	+1	+1	+8	+3
5.0	0	+1	+1	+4	+15
10.0	0	+1	-1	-1	+4
20.0	0	0	+1	-2	+2
30.0	0	0	0	-5	+3
50.0	0	0	0	+2	-6

* Concentrations were compared with those computed with ALPHA equal to 0.2.

FREQUENCY OF PUFF COMBINATION -- ISTTIM

The parameter ISTTIM controls the frequency at which the model investigates the puffs to determine if they are to be combined. Interrogating the puffs every time step is time consuming in itself; therefore, ISTTIM is specified in multiples of the time step. For example, if one desires to test for puff combination every third puff release, then ISTTIM equals 3. ISTTIM also controls the frequency puffs are interrogated to determine whether they are outside the modeling region.

Figure 12 shows the relationship between execution time and ISTTIM. It is apparent from the figure that computer costs are a minimum when ISTTIM is between 3 and 8. Execution time increases as ISTTIM approaches 1 because the code interrogating the puffs is executed more often. It also increases when ISTTIM is greater than 8 because the program must keep track of more puffs.

PUFF SIZE -- STANUM

The parameter STANUM determines whether or not a concentration estimate is made for a given puff at a given receptor. STANUM is the number of lateral standard deviations defining the maximum puff-receptor distance for concentration estimates. For example, if STANUM is equal to 5, then concentration calculations are made only if the puff center is within $5\sigma_r$ of the receptor.

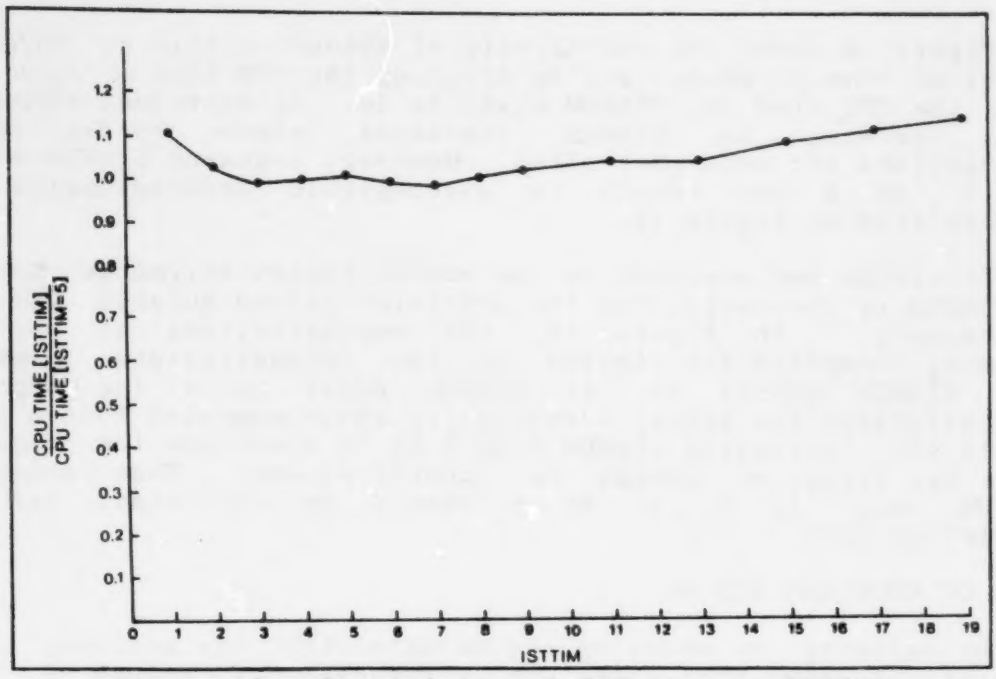


Figure 12. Sensitivity of CPU time to ISTTIM.

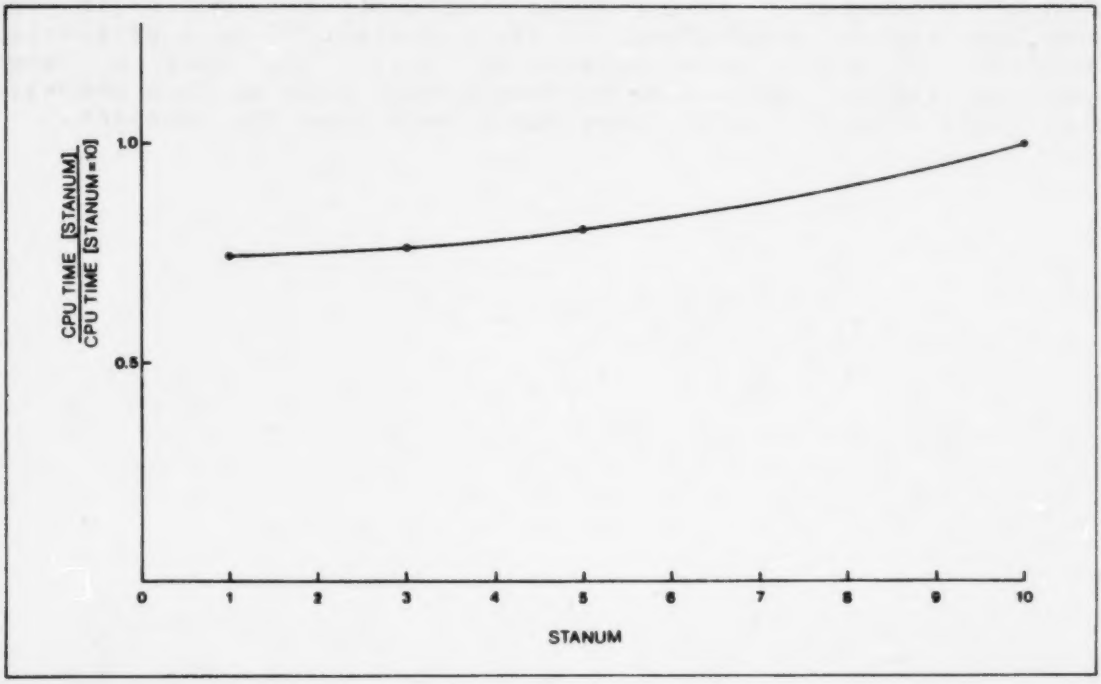


Figure 13. Sensitivity of CPU time to STANUM.

Figure 13 shows the sensitivity of execution time to STANUM. Execution time is normalized by dividing the CPU time of each run with the CPU time for STANUM equal to 10. As expected, computer costs increase as STANUM increases since concentration calculations are made more often. However, choosing STANUM equal to 1 or 2 may result in unacceptable underestimates as demonstrated by Figure 14.

Precision and accuracy in the concentration estimates improve as STANUM is increased, but the precision gained quickly becomes unnecessary. In Figure 14, the concentrations at various downwind receptors are divided by the concentrations computed when STANUM equals 10. At STANUM equal to 3, the computed concentrations are almost identical to those computed when STANUM equals 10. Increasing STANUM from 5 to 10 increases the computer costs but yields no change in concentrations. Thus choosing STANUM equal to 3, 4, or 5 should be sufficient for any simulation case.

SIZE OF MODELING REGION

By defining the modeling region carefully, the user may save substantial computer costs as illustrated in Figure 15. For example, it makes little sense to extend the modeling region 50 kilometers downstream of the source when all the receptors are within 5 kilometers. INPUFF keeps track of all puffs in the modeling region regardless of their distance from a particular receptor. It might, nevertheless, be useful to have a large modeling region under some circumstances, such as in a dramatic wind shift situation that blows puffs back over the receptors.

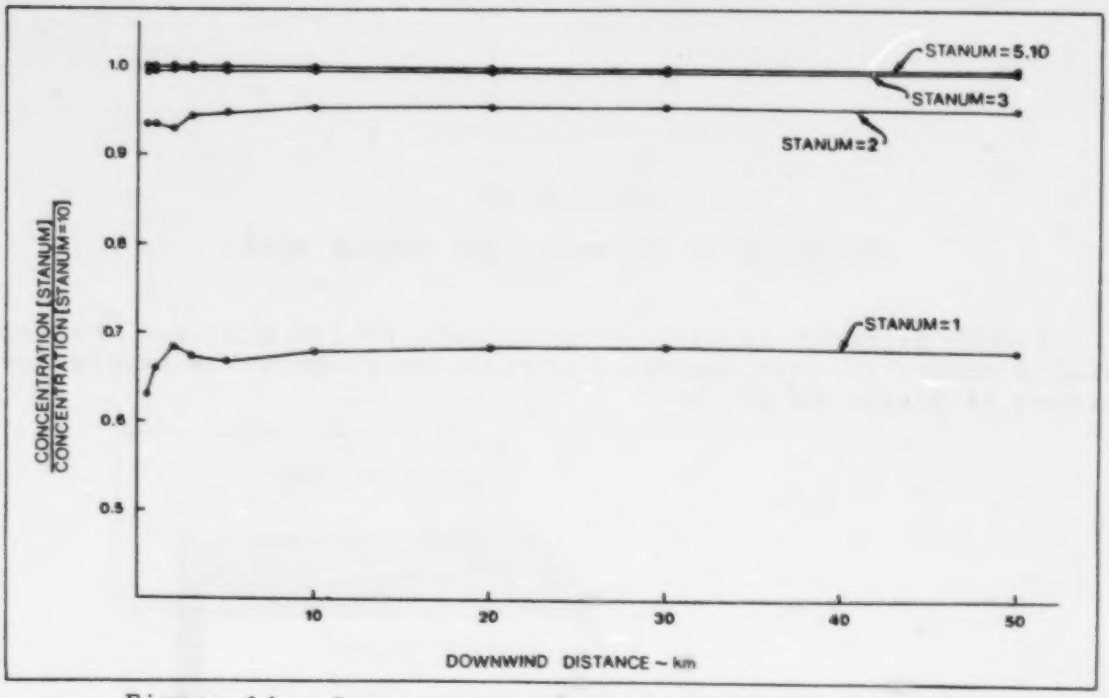


Figure 14. Sensitivity of concentrations to STANUM.

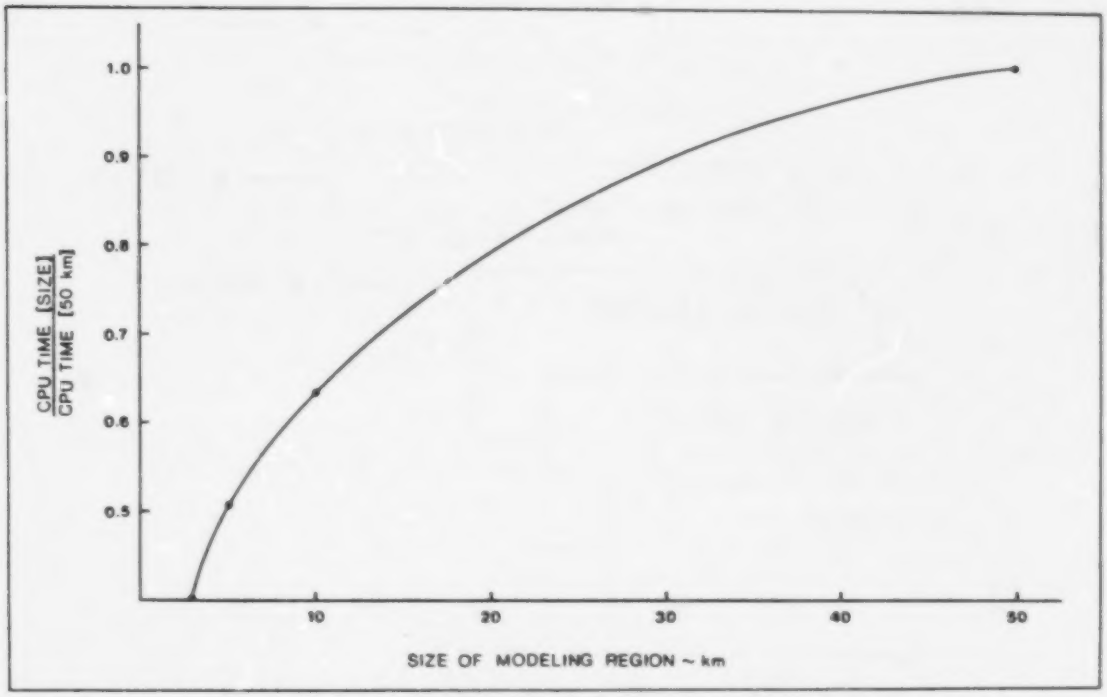


Figure 15. Sensitivity of CPU time to size of modeling region.

SECTION 10

EXECUTION OF THE MODEL AND SAMPLE TEST

INPUFF produces an error-free compile on IBM MVS and UNIVAC EXEC 8 computers with comparable execution results. A sample job stream is presented below.

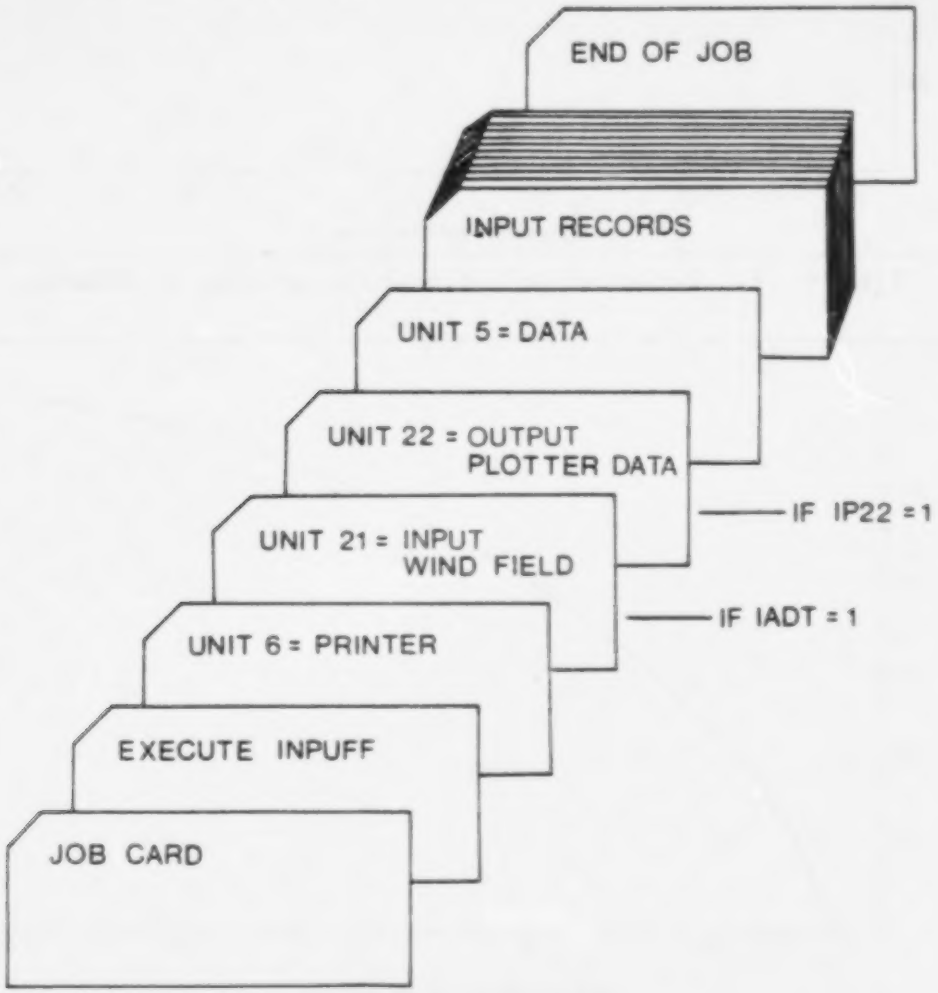


Figure 16. Sample job stream for INPUFF.

Sample test data for model verification are as follows:

```
INPUFF VERIFICATION RUN
1,0,0,0,0,0
2,3600,-1,3600,0,5,6,1,7,10.
0.,0.,25.,40.,5.,1.,1000.
0.,20.,2750.,165.,425.,4.5,38.,0.,1.5,1.5,0.,0.
 0.5,20.,0.
 1.0,20.,0.
 2.0,20.,0.
 3.0,20.,0.
 5.0,20.,0.
10.0,20.,0.
20.0,20.,0.
(F4.0,F3.0,F6.0,I2,3F5.0,F3.0)
270. 3. 1500. 4 .112 .175 290. .5
270. 3. 1500. 4 .112 .175 290. .5
```

A job stream for a UNIVAC EXEC 8 system might have the following form:

```
@RUN,R/R JOB-ID,ETC
@ASG,A MODELS*LOAD.
@ASG,A WINDS          } Not needed for
@USE 21,WINDS         } verification run
@ASG,R PLOT           } Not needed for
@USE 22,PLOT          } verification run
@XQT MODELS*LOAD.INPUFF
(input records shown above)
@FIN
```

The following is a sample job stream for an IBM system under OS or MVS. Units 21 and 22 are assumed to have been preallocated.

```
//JOBID    JOB  (PROJ,ACCT,OTHER),CLASS=A,TIME=1
//XINPUFF  EXEC PGM=INPUFF,TIME=(,30)
//STEPLIB  DD   DSN=USER.MODELS.LOAD,DISP=SHR
//FT21F001 DD   DSN=USER.WINDS.DATA,DISP=SHR  } Not needed for
//FT22F001 DD   DSN=USER.PLOT.DATA,DISP=SHR   } verification run
//FT06F001 DD   SYSOUT=A
//FT05F001 DD   *
(input records shown above)
/*
//
```

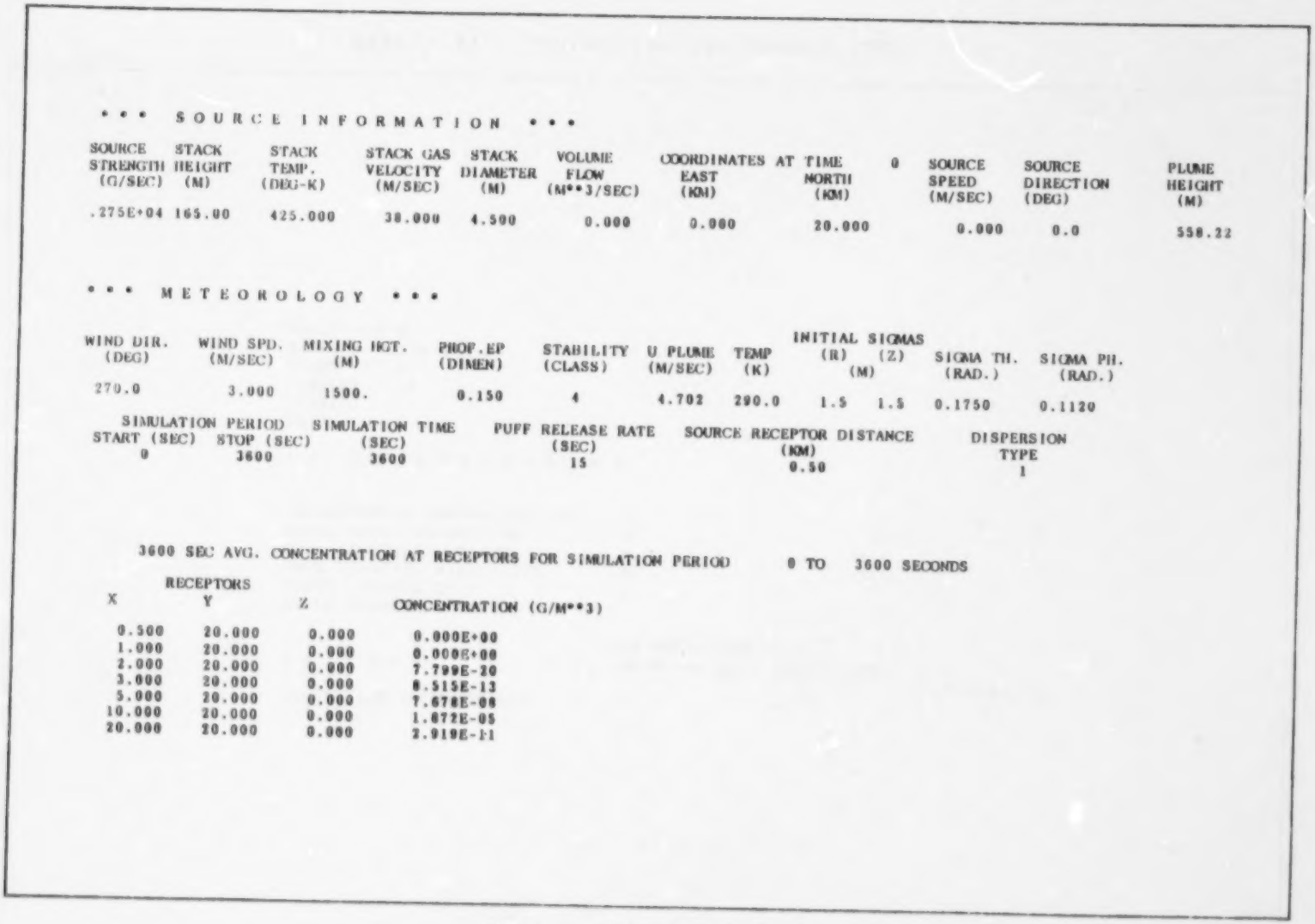
A sample job stream for a CDC system under Scope 3.14 may look as follows:

```
XX,T05,P4.
USER,HALE,EPA.
PROJECT,*PRJ*XX.
ATTACH,LIB,MODELSLIB,ID=XX.
ATTACH,TAPE21,WINDS,ID=XX.   Not needed for
ATTACH,TAPE22,PLOT,ID=XX.    verification run
LIBARY,LIB.
INPUFF.
*
(input records shown above)
*
```

Figure 17 provides the output for the sample test. Users may verify the proper execution of the program by comparing their results with those given in the figure.

```
INPUFF VERIFICATION RUN

O P T I O N S          A "1" INDICATES THAT THE OPTION          VERSION 84107
                       HAS BEEN EXERCISED

STACK DOWNWASH                    1
UPDATE SOURCE DATA                0
USER SUPPLIED WIND FIELD          0
UNIT 22 OUTPUT OPTION             0
PRINT PUFF INFORMATION            0
INTERMEDIATE CONCENTRATIONS       0


I N P U T   P A R A M E T E R S

ISIM=      0
ISTTIM=      5
STANUM= 5.00
ALPHA= 1.00
SYMAX=    1000.0
ANHGT= 10.0
```

Figure 17. Output for the sample test.



• • • SOURCE INFORMATION • • •

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 0 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.275E+04	165.00	425.000	38.000	4.500	0.000	0.000	20.000	0.000	0.0	558.22

• • • METEOROLOGY • • •

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
270.0	3.000	1500.	0.150	4	4.702	290.0	1.5	1.5	0.1750	0.1120

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
0	3600	3600	15	0.50	1

3600 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 0 TO 3600 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
0.500	20.000	0.000	0.000E+00
1.000	20.000	0.000	0.000E+00
2.000	20.000	0.000	7.799E-20
3.000	20.000	0.000	8.515E-13
5.000	20.000	0.000	7.678E-08
10.000	20.000	0.000	1.672E-05
20.000	20.000	0.000	2.919E-11

Figure 17. (continued)

*** SOURCE INFORMATION ***

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 3600 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.275E+04	165.00	425.000	38.000	4.500	0.000	0.000	20.000	0.000	0.0	558.22

*** METEOROLOGY ***

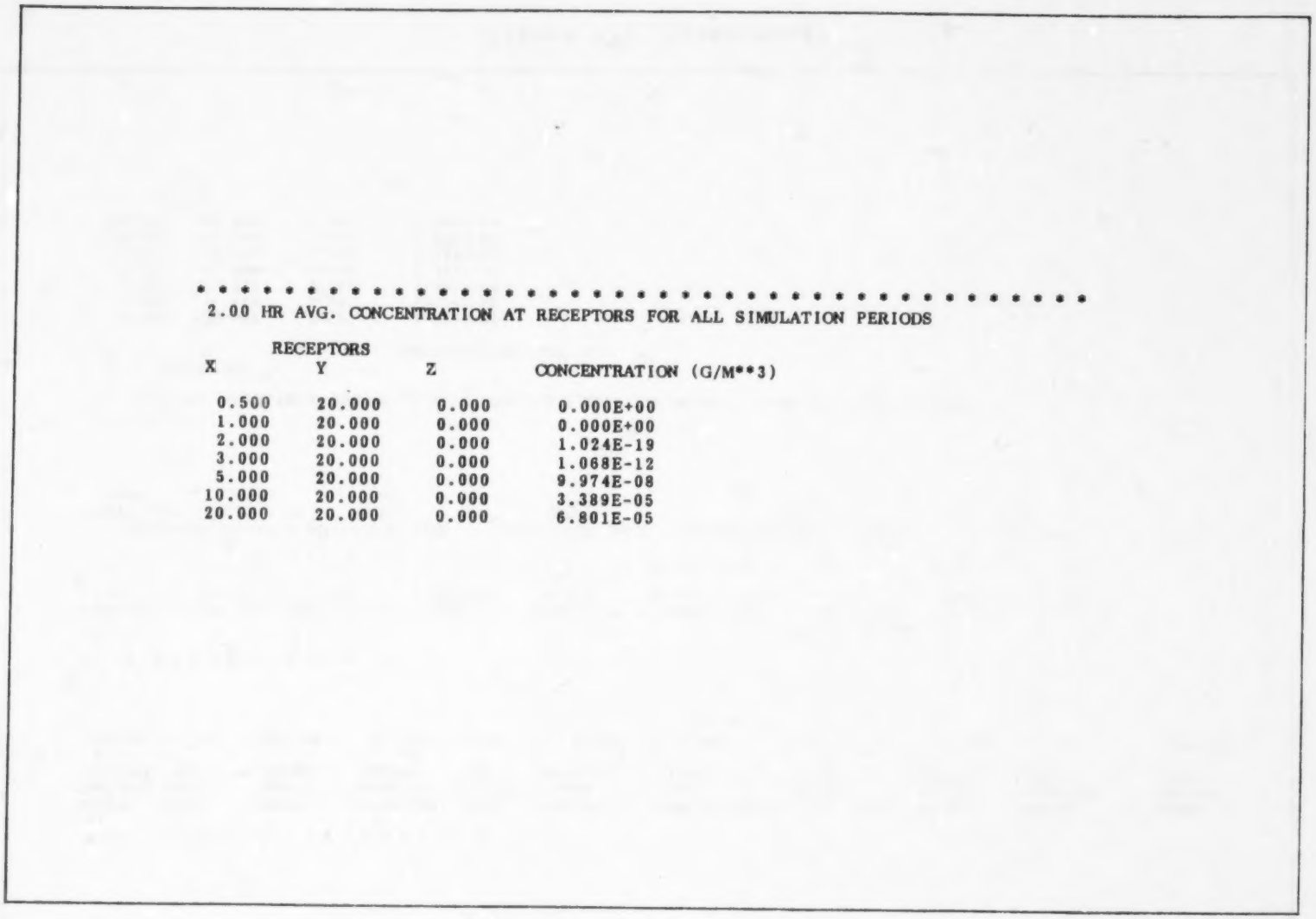
WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
270.0	3.000	1500.	0.150	4	4.702	290.0	1.5	1.5	0.1750	0.1120

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
3600	7200	3600	15	0.50	1

3600 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 3600 TO 7200 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
0.500	20.000	0.000	0.000E+00
1.000	20.000	0.000	0.000E+00
2.000	20.000	0.000	1.268E-19
3.000	20.000	0.000	1.285E-12
5.000	20.000	0.000	1.227E-07
10.000	20.000	0.000	4.906E-05
20.000	20.000	0.000	1.360E-04

Figure 17. (continued)



2.00 HR AVG. CONCENTRATION AT RECEPTORS FOR ALL SIMULATION PERIODS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
0.500	20.000	0.000	0.000E+00
1.000	20.000	0.000	0.000E+00
2.000	20.000	0.000	1.024E-19
3.000	20.000	0.000	1.068E-12
5.000	20.000	0.000	9.974E-08
10.000	20.000	0.000	3.389E-05
20.000	20.000	0.000	6.801E-05

Figure 17. (continued)

SECTION 11

INTERPRETATION OF OUTPUT

The output of INPUFF has ten parts, three of which are optional. The output begins with printing the title of the run, which can be up to 80 characters in length. The next printed information is a list of options, followed by a list of the input parameters. Next are the source data followed by a printout of meteorological conditions used in the execution of the model for the current simulation period. These are followed by five pieces of information regarding how INPUFF simulates the release, including: simulation period, simulation time, puff release rate, minimum source-receptor distance, and dispersion type. The next two output sections are optional. If IPIC = 1, then intermediate concentrations are written every INC seconds. The time period for which the averages are appropriate is printed in the first line of the intermediate concentration output. If IPCC = 1, then information on each puff is printed each ITIME in addition to average concentrations at each receptor. Finally, a table of average concentrations is output giving averages for each receptor for all meteorological periods.

There is one other optional output available to the user. If IP22 = 1, then information is written to unit 22, which can be used later for plotting purposes.

The input stream and output listing of example problems 1 and 2 of Section 6 are presented in the next two sections. The reader is referred to the earlier section for the physical description of each problem. Intricacies of the input data are discussed and the output listing is annotated for ease of interpretation.

EXAMPLE 1 -- MOVING SOURCE

This example demonstrates an unique feature of INPUFF that allows the source to move at a constant speed and direction over a specified time (ITIME). If the source is changing speed and direction more frequently than the meteorology, then ITIME can be adjusted to match the frequency of source changes. The meteorology is also changed accordingly. Table 11 lists the input data; outputs of the example problem are given in Figure 18. Since IPCC = 1, the output includes puff information printed for each ITIME.

TABLE 11. INPUT DATA FOR EXAMPLE 1

Record	Record Type
EXAMPLE 1 MOVING SOURCE	1
1,1,0,1,1,0	2
2,1200,-1,60,0,5,6,1,8,10.	5
0.,0.,25.,15.,10.,.75,1000.	6
0.,.2,600.,30.,390.,2.,15.,0.,1.,1.,90.,2.	7
1.54,1.19,0.	8
1.65,1.35,0.	8
2.,1.5,0.	8
2.35,1.35,0.	8
1.08,1.38,0.	8
1.3,1.7,0.	8
2.,2.,0.	8
2.7,1.7,0.	8
(F4.0,F4.0,F6.0,I2,3F5.0,F3.0)	9
180. 3.5 3000. 3 .074 .105 290. .5	10
170. 4.0 3000. 4 .047 .067 288. .5	10
600.,30.,390.,2.,15.,0.,1.,1.,45.,2.	11

Note that the source information is updated every 20 minutes for two periods. If, however, the source speed and direction were changing every 5 minutes, NTIME could be changed to 8 and ITIME to 300 seconds. There would now be eight record type 10's and seven record type 11's. The first four meteorology records would be the same, and the second four would also be the same. In this example, the source speed and direction are assumed to change at 20-minute intervals.

The information printed for each puff includes: puff number and coordinates, time of puff release, total mass of the puff, σ_r and σ_z for the puff, and its dispersion key. Because the puffs combine as they travel downwind, the puff's characteristics are adjusted each time it combines with another puff. For example, puff 1 has a total mass of 60,000 grams. Since the source strength is 600 g/sec and the puff release rate is 20 seconds, this represents the combination of five puffs. All the parameters are affected by puff combinations except the dispersion key (KEYP). Puffs with different KEYP values do not combine.

Plots of concentration versus time for each of the eight receptors are shown in Figure 19. The coordinates of each receptor are printed at the top of each plot. The input data used in the execution of the plot programs are very short and are shown below.

Input Data Records	Data
1	1
2	-1, 8, 2, 5., 5.
3	1, 2, 3, 4, 5, 6, 7, 8

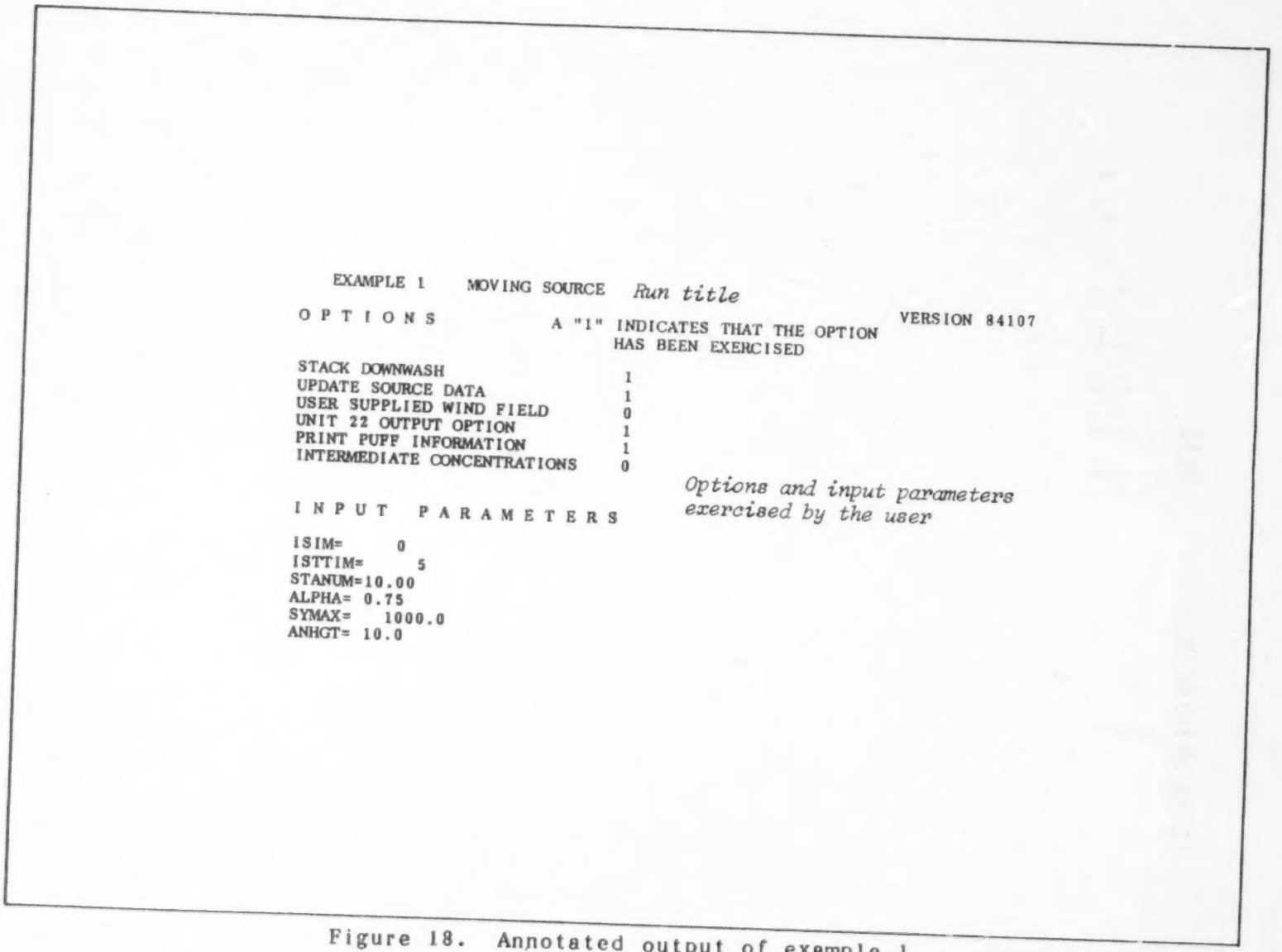


Figure 18. Annotated output of example 1.

• • • SOURCE INFORMATION • • •

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 0 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.600E+03	30.00	390.000	15.000	2.000	0.000	0.000	0.200	2.000	90.0	113.47

• • • METEOROLOGY • • •

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
180.0	3.500	3000.	0.100	3	4.462	290.0	1.0	1.0	0.1050	0.0740

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
0	1200	1200 ← *ITIME*	20 ← *ISTEP*	0.50 ← *CDIS*	1

} *Puff simulation information*

P-G dispersion scheme

PUFF#	*puff location (m)* X	Y	Z	*release time (sec)* TIME	*puff mass (g)* TOTAL Q	σy SY	σz SZ	KEYP
1	60.002	5420.866	113.471	30	48000.00	459.583	277.755	1
2	210.002	5086.195	113.471	105	36000.00	433.114	261.459	1
3	340.002	4796.146	113.471	170	48000.00	410.007	247.259	1
•								•
•								•
•								•
31	2319.999	378.491	113.471	1160	12000.00	21.965	13.362	1
32	2359.999	289.246	113.471	1180	12000.00	11.953	7.468	1
33	2399.999	200.000	113.471	1200	12000.00	1.000	1.000	1

Since IPCC = 1, the location, release time, mass, size, and dispersion key are printed for each puff within the modeling region.

ITIME → 1200 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 0 TO 1200 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	1.353E-04
1.650	1.350	0.000	1.669E-04
2.000	1.500	0.000	2.168E-05
2.350	1.350	0.000	1.211E-08
1.080	1.380	0.000	1.806E-04
1.300	1.700	0.000	2.206E-04
2.000	2.000	0.000	3.675E-06
2.700	1.700	0.000	2.921E-14

Average concentrations at each receptor are printed at the end of each meteorological period.

Figure 18. (continued)

Next meteorological period. Source parameters and meteorology are different from the previous period.

• • • SOURCE INFORMATION • • •

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 1200 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.600E+03	30.00	390.000	15.000	2.000	0.000	2.400	0.200	2.000	45.0	100.17

• • • METEOROLOGY • • •

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
170.0	4.000	3000.	0.150	4	5.652	288.0	1.0	1.0	0.0670	0.0470

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
1200	2400	1200	12	0.50	1

PUFF#	X	Y	Z	TIME	TOTAL Q	SY	SZ	KEYP
1	7.340	9589.681	113.471	592	60000.00	595.576	273.751	1
2	207.339	9143.456	113.471	692	60000.00	563.776	253.405	1
3	407.339	8697.231	113.471	792	60000.00	531.498	233.123	1
•								•
•								•
•								•
45	4039.568	1996.690	100.167	2376	7200.00	11.662	6.484	1
46	4068.315	1946.872	100.167	2388	7200.00	6.552	3.967	1
47	4097.062	1897.054	100.167	2400	7200.00	1.000	1.000	1

1200 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 1200 TO 2400 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	1.154E-07
1.650	1.350	0.000	7.611E-06
2.000	1.500	0.000	1.233E-04
2.350	1.350	0.000	1.310E-05
1.080	1.380	0.000	4.781E-10
1.300	1.700	0.000	2.136E-06
2.000	2.000	0.000	1.803E-04
2.700	1.700	0.000	1.285E-05

Average concentrations for the second meteorological period.

Figure 18. (continued)

Length of simulation time

0.67 HR AVG. CONCENTRATION AT RECEPTORS FOR ALL SIMULATION PERIODS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	6.770E-05
1.650	1.350	0.000	8.725E-05
2.000	1.500	0.000	7.247E-05
2.350	1.350	0.000	6.555E-06
1.080	1.380	0.000	9.032E-05
1.300	1.700	0.000	1.114E-04
2.000	2.000	0.000	9.198E-05
2.700	1.700	0.000	6.423E-06

Average concentrations at each receptor over the modeling period.

Figure 18. (continued)

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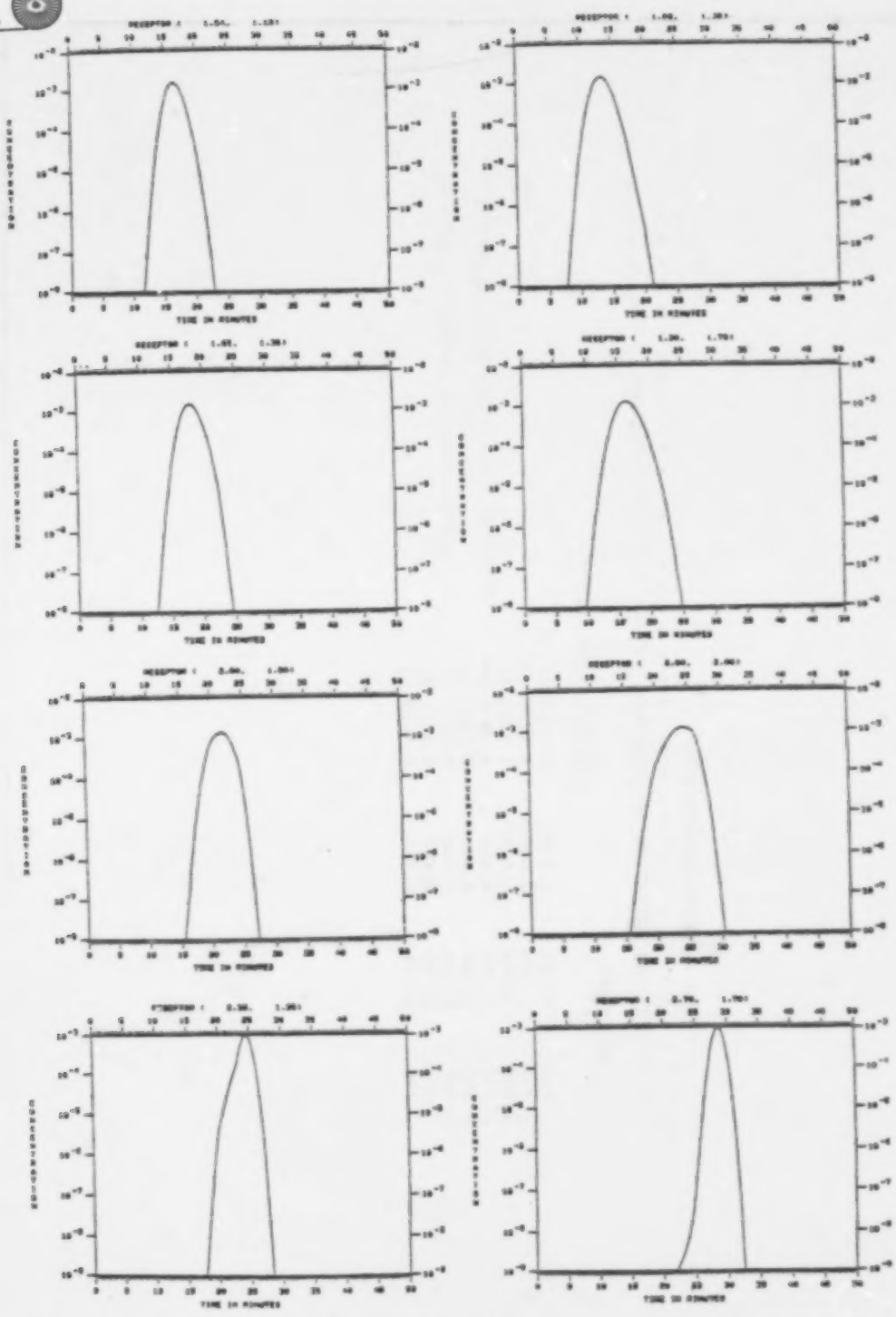

Figure 19. Concentration versus time plots for example 1.

EXAMPLE 2 -- LOW LEVEL SOURCE WITH LOW WIND SPEED CONDITIONS

This problem illustrates the model simulation for a low level release during conditions of light and variable winds. The input data stream is shown in Table 12 and the abridged output in Figure 20. A very important difference between this example and the previous example is that for this example DISKEY on record 5 has been assigned a value of 2. Dispersion downwind of the source is no longer characterized by travel distance but by travel time using the on-site dispersion scheme. The values assigned to σ_a and σ_e are not used in the P-G characterization of dispersion. However, in the on-site scheme, σ_y and σ_z are functions of σ_a and σ_e. If measures of these fluctuation statistics are available, they should be used. If none are available, then typical values can be used based on the state of the atmosphere.

In this example, twelve simulation periods of 10-minute duration are used to simulate the 2-hour release. The atmosphere is stable with large fluctuations in the wind direction. σ_a has been assigned a large value, typical of low wind speed conditions. The strength of the source is decaying with time; initially the source strength is 825 g/sec, but by the 12th period it has dropped to 12 g/sec.

In this simulation, average concentrations at each receptor are printed every 10 minutes. The puff locations at the end of each 10 minute period are plotted in Figure 21. The input data for the plot program are shown below:

Input Data Record	Data
1	2
2	0., 0., 5., 5., 5., 5.

Circles drawn around the centers of the puff positions have a radius equal to σ_r.

TABLE 12. INPUT DATA FOR EXAMPLE 2

Record	Record type
EXAMPLE 2 LOW LEVEL SOURCE LOW WIND SPEED	1
0,1,0,1,0,0	2
12,600,-1,300,0,5,6,2,10,10.	5
0.,0.,25.,15.,10.,1.,1000.	6
2.,1.,825.,3.,290.,.5,10.,0.,1.,1.,0.,0.	7
1.54,1.19,0.	8
1.65,1.35,0.	8
2.,1.5,0.	8
2.35,1.35,0.	8
2.46,1.19,0.	8
1.08,1.38,0.	8
1.3,1.7,0.	8
2.,2.,0.	8
2.7,1.7,0.	8
2.92,1.38,0.	8
(F4.0,F3.0,F6.0,I2,3F5.0,F3.0)	9
180. .5 5000. 6 .035 .393 290. .5	10
210. .5 5000. 6 .035 .393 290. .5	10
175. .5 5000. 6 .035 .393 290. .5	10
145. .5 5000. 6 .035 .393 290. .5	10
155. .5 5000. 6 .035 .393 290. .5	10
210. .5 5000. 6 .035 .393 290. .5	10
200. .5 5000. 6 .035 .393 290. .5	10
182. .5 5000. 6 .035 .393 290. .5	10
170. .5 5000. 6 .035 .393 290. .5	10
195. .5 5000. 6 .035 .393 290. .5	10
185. .5 5000. 6 .035 .393 290. .5	10
195. .5 5000. 6 .035 .393 290. .5	10
562.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
383.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
261.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
178.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
121.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
83.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
56.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
38.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
26.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
18.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11
12.,3.,290.,.5,10.,0.,1.,1.,0.,0.	11

```
     EXAMPLE 2     LOW LEVEL SOURCE LOW WIND SPEED

O P T I O N S                                                  VERSION 84107
                          A "1" INDICATES THAT THE OPTION
                                HAS BEEN EXERCISED

STACK DOWNWASH                          0
UPDATE SOURCE DATA                      1
USER SUPPLIED WIND FIELD                0
UNIT 22 OUTPUT OPTION                   1
PRINT PUFF INFORMATION                  0
INTERMEDIATE CONCENTRATIONS             0


I N P U T   P A R A M E T E R S

ISIM=      0
ISTTIM=      5
STANUM=10.00
ALPHA= 1.00
SYMAX=    1000.0
ANHGT= 10.0
```

Figure 20. Annotated output of example 2.

*** SOURCE INFORMATION ***

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 0 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.325E+03	3.00	290.000	10.000	0.500	0.000	2.000	1.000	0.000	0.0	11.50

*** METEOROLOGY ***

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
180.0	0.500	5000.	0.350	6	0.525	290.0	1.0	1.0	0.3930	0.0350

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
0	600	600	100	0.50	2

600 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 0 TO 600 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	6.153E-15
1.650	1.350	0.000	1.533E-10
2.000	1.500	0.000	9.132E-07
2.350	1.350	0.000	1.533E-10
2.460	1.190	0.000	6.153E-15
1.080	1.380	0.000	0.000E+00
1.300	1.700	0.000	0.000E+00
2.000	2.000	0.000	0.000E+00
2.700	1.700	0.000	0.000E+00
2.920	1.380	0.000	0.000E+00

Figure 20. (continued)

*** SOURCE INFORMATION ***

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 600 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.562E+03	3.00	290.000	10.000	0.500	0.000	2.000	1.000	0.000	0.0	11.50

*** METEOROLOGY ***

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
210.0	0.500	5000.	0.350	6	0.525	290.0	1.0	1.0	0.3930	0.0350

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
600	1200	600	100	0.50	2

600 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 600 TO 1200 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	1.575E-10
1.650	1.350	0.000	2.521E-07
2.000	1.500	0.000	3.030E-03
2.350	1.350	0.000	5.136E-04
2.460	1.190	0.000	3.859E-06
1.080	1.380	0.000	7.277E-21
1.300	1.700	0.000	1.028E-14
2.000	2.000	0.000	4.525E-07
2.700	1.700	0.000	3.338E-08
2.920	1.380	0.000	2.713E-12

Figure 20. (continued)

*** SOURCE INFORMATION ***

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 1200 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.383E+03	3.00	290.000	10.000	0.500	0.000	2.000	1.000	0.000	0.0	11.50

*** METEOROLOGY ***

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
175.0	0.500	5000.	0.350	6	0.525	290.0	1.0	1.0	0.3930	0.0350

SIMULATION PERIOD START (SEC)	SIMULATION PERIOD STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
1200	1800	600	100	0.50	2

600 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 1200 TO 1800 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	2.960E-08
1.650	1.350	0.000	8.590E-06
2.000	1.500	0.000	1.287E-02
2.350	1.350	0.000	1.617E-03
2.460	1.190	0.000	1.456E-05
1.080	1.380	0.000	5.749E-13
1.300	1.700	0.000	2.048E-08
2.000	2.000	0.000	3.338E-03
2.700	1.700	0.000	2.508E-05
2.920	1.380	0.000	4.712E-09

Output is abridged. The following meteorological periods are missing from the sample output:

1800 to 2400 sec,
2400 to 3000 sec,
3000 to 3600 sec,
3600 to 4200 sec,
4200 to 4800 sec,
4800 to 5400 sec,
5400 to 6000 sec, and
6000 to 6600 sec.

Figure 20. (continued)

*** SOURCE INFORMATION ***

SOURCE STRENGTH (G/SEC)	STACK HEIGHT (M)	STACK TEMP. (DEG-K)	STACK GAS VELOCITY (M/SEC)	STACK DIAMETER (M)	VOLUME FLOW (M**3/SEC)	COORDINATES AT TIME 6600 EAST (KM)	NORTH (KM)	SOURCE SPEED (M/SEC)	SOURCE DIRECTION (DEG)	PLUME HEIGHT (M)
.120E+02	3.00	290.000	10.000	0.500	0.000	2.000	1.000	0.000	0.0	11.50

Source strength has decayed to 12 g/sec from an original value of 825 g/sec.

*** METEOROLOGY ***

WIND DIR. (DEG)	WIND SPD. (M/SEC)	MIXING HGT. (M)	PROF.EP (DIMEN)	STABILITY (CLASS)	U PLUME (M/SEC)	TEMP (K)	INITIAL SIGMAS (R) (M)	(Z) (M)	SIGMA TH. (RAD.)	SIGMA PH. (RAD.)
195.0	0.500	5000.	0.350	6	0.525	290.0	1.0	1.0	0.3930	0.0350

SIMULATION PERIOD START (SEC)	STOP (SEC)	SIMULATION TIME (SEC)	PUFF RELEASE RATE (SEC)	SOURCE RECEPTOR DISTANCE (KM)	DISPERSION TYPE
6600	7200	600	100	0.50	2

600 SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMULATION PERIOD 6600 TO 7200 SECONDS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	1.190	0.000	4.081E-09
1.650	1.350	0.000	6.713E-07
2.000	1.500	0.000	5.585E-04
2.350	1.350	0.000	2.517E-05
2.460	1.190	0.000	2.147E-07
1.080	1.380	0.000	1.294E-10
1.300	1.700	0.000	3.769E-07
2.000	2.000	0.000	3.437E-03
2.700	1.700	0.000	1.465E-05
2.920	1.380	0.000	1.026E-08

Figure 20. (continued)

2.00 HR AVG. CONCENTRATION AT RECEPTORS FOR ALL SIMULATION PERIODS

RECEPTORS X	Y	Z	CONCENTRATION (G/M**3)
1.540	.90	0.000	1.346E-05
1.650	1.350	0.000	5.363E-04
2.000	1.500	0.000	4.846E-03
2.350	1.350	0.000	3.234E-04
2.460	1.190	0.000	3.827E-06
1.080	1.380	0.000	1.945E-07
1.300	1.700	0.000	1.803E-04
2.000	2.000	0.000	1.630E-02
2.700	1.700	0.000	4.375E-05
2.920	1.380	0.000	3.052E-08

Figure 20. (continued)

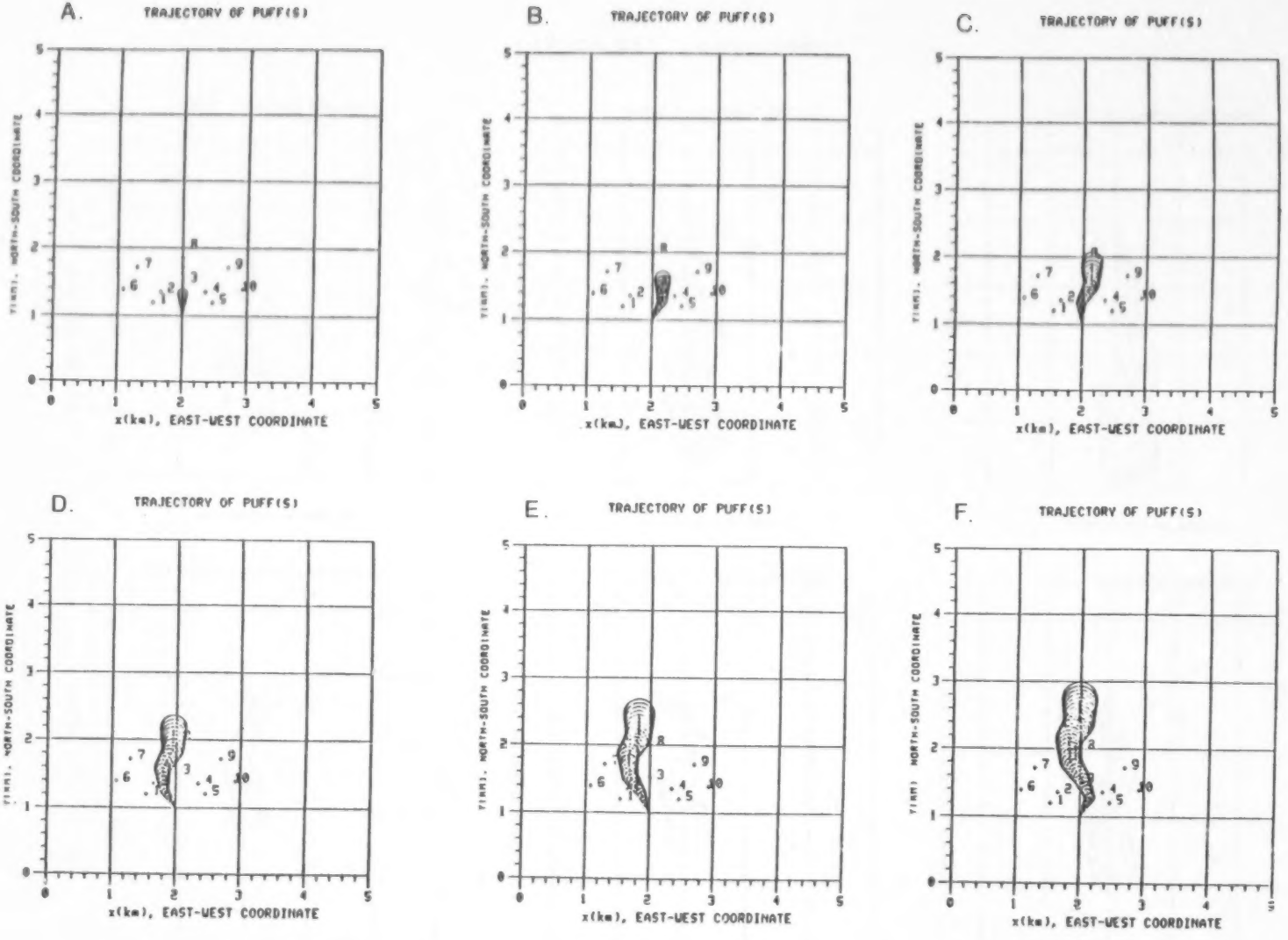

Figure 21. Puff locations at the end of each simulation period.
A - L represents 10-minute intervals

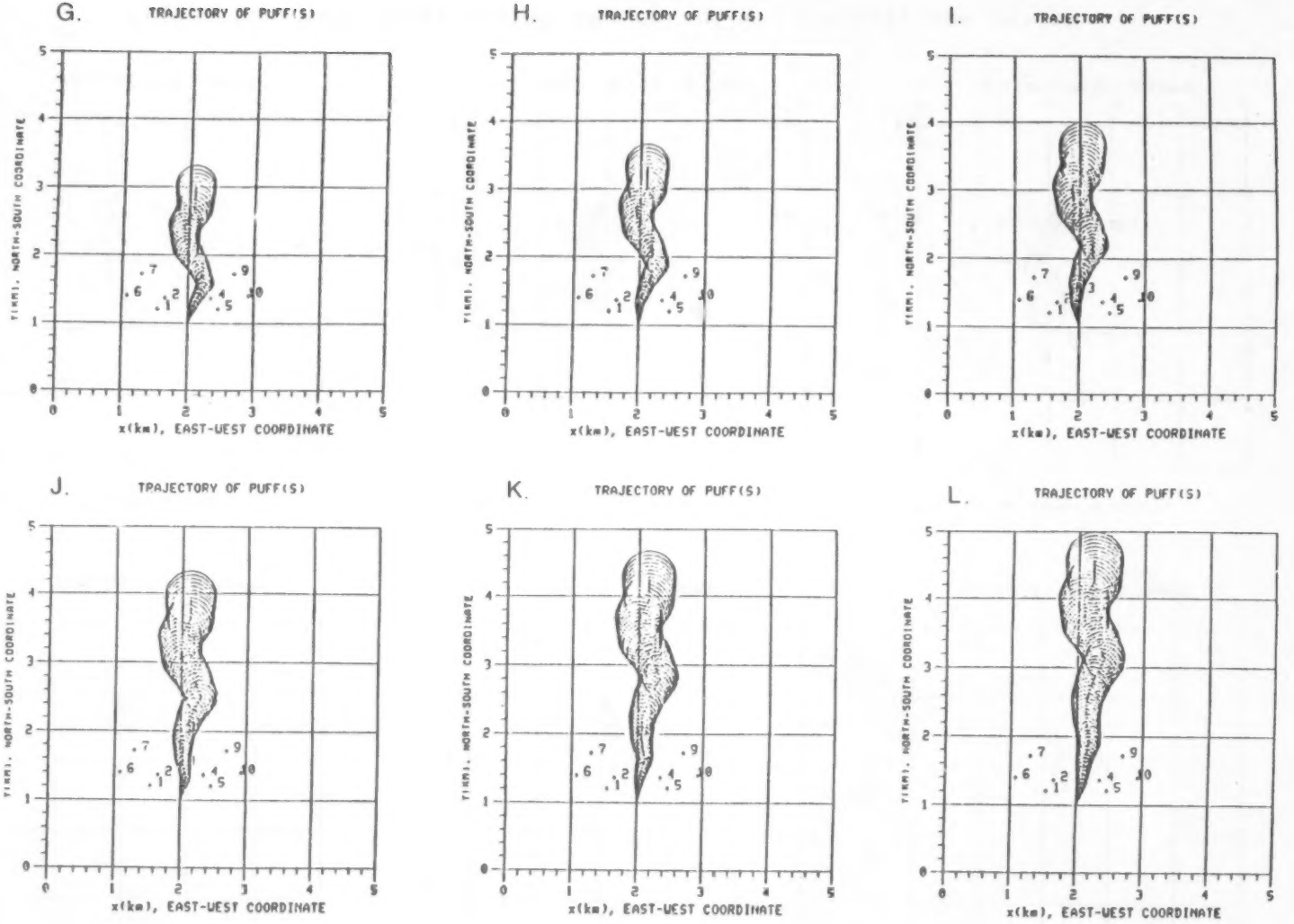

Figure 21. (continued)

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APPENDIX A

PLUME RISE

The use of the methods of Briggs to estimate plume rise and effective height of emission are discussed below. In all calculations, it is assumed that actual or estimated wind speed at stack top, u(h), is available.

STACK DOWNWASH

To consider stack downwash, the physical stack height is modified following Briggs (1973, p. 4). The h' is found from

$$h' = h + 2\{[v_s/u(h)] - 1.5\}d \quad \text{for } v_s < 1.5u(h), \qquad \text{(A-1)}$$

$$h' = h \quad \text{for } v_s \geq 1.5u(h),$$

where h is physical stack height (meters), v_s is stack gas velocity (meters per second), and d is inside stack-top diameter (meters). The h' is used throughout the plume height computation. If stack downwash is not considered, h' = h in the equations.

BUOYANCY FLUX

For most plume rise calculations, the value of the Briggs buoyancy flux parameter, F (m^4/s^3), is needed. The following equation is equivalent to Briggs' Eq. 12 (1975, p. 63):

$$F = (gv_s d^2 \Delta T)/(4T_s), \qquad \text{(A-2)}$$

where $\Delta T = T_s - T$, T_s is stack gas temperature (degrees kelvin), and T is ambient air temperature (degrees kelvin).

UNSTABLE OR NEUTRAL: CROSSOVER BETWEEN MOMENTUM AND BUOYANCY

For cases with stack gas temperature greater than or equal to ambient air temperature, it must be determined whether the plume rise is dominated by momentum or buoyancy. The crossover temperature difference $(\Delta T)_c$ is determined for (1) F less than 55 and (2) F greater than or equal to 55. If the difference between stack gas temperature and ambient air temperature, ΔT, exceeds or equals the $(\Delta T)_c$, plume rise is assumed to be buoyancy dominated; if the difference is less than $(\Delta T)_c$, plume rise is assumed to be

momentum dominated (see below).

The crossover temperature difference is found by setting Briggs' Eq. 5.2 (1969, p. 59) equal to the combination of Briggs' Eqs. 6 and 7 (1971, p. 1031) and solving for ΔT. For F less than 55,

$$(\Delta T)_c = 0.0297 v_s^{1/3} T_s / d^{2/3}. \quad \text{(A-3)}$$

For F equal to or greater than 55,

$$(\Delta T)_c = 0.00575 v_s^{2/3} T_s / d^{1/3}. \quad \text{(A-4)}$$

UNSTABLE OR NEUTRAL: BUOYANCY RISE

For situations where ΔT exceeds or is equal to $(\Delta T)_c$ as determined above, buoyancy is assumed to dominate. The distance to final rise x_f (in kilometers) is determined from the equivalent of Briggs' Eq. 7 (1971, p. 1031), and the distance to final rise is assumed to be $3.5x^*$, where x^* is the distance at which atmospheric turbulence begins to dominate entrainment. For F less than 55,

$$x_f = 0.049 F^{5/8}. \quad \text{(A-5)}$$

For F equal to or greater than 55,

$$x_f = 0.119 F^{2/5}. \quad \text{(A-6)}$$

The plume height, H (in meters), is determined from the equivalent of the combination of Briggs' Eqs. 6 and 7 (1971, p. 1031). For F less than 55,

$$H = h' + 21.425 F^{3/4} / u(h), \quad \text{(A-7)}$$

and for F equal to or greater than 55,

$$H = h' + 38.71 F^{3/5} / u(h). \quad \text{(A-8)}$$

UNSTABLE OR NEUTRAL: MOMENTUM RISE

For situations where the stack gas temperature is less than the ambient air temperature, it is assumed that the plume rise is dominated by momentum. Also, if ΔT is less than $(\Delta T)_c$ from Eq. A-3 or A-4, it is assumed that the plume rise is dominated by momentum. The plume height is calculated from Briggs' Eq. 5.2 (1969, p. 59):

$$H = h' + 3 d v_s / u(h). \quad \text{(A-9)}$$

Briggs (1969) suggests that this equation is most applicable when v_s/u is greater than 4. Since momentum rise occurs quite close

to the point of release, the distance to final rise is set equal to zero.

STABILITY PARAMETER

For stable situations, the stability parameter s is calculated from the following equation (Briggs, 1971, p. 1031):

$$s = g(\partial\theta/\partial z)/T. \qquad \text{(A-10)}$$

As an approximation, for stability class E, $\partial\theta/\partial z$ is taken as 0.02 K/m, and for stability class F, $\partial\theta/\partial z$ is taken as 0.035 K/m.

STABLE: CROSSOVER BETWEEN MOMENTUM AND BUOYANCY

For cases with stack gas temperature greater than or equal to ambient air temperature, it must be determined whether the plume rise is dominated by momentum or buoyancy. The crossover temperature difference $(\Delta T)_c$ is found by setting Briggs' Eq. 59 (1975, p. 96) equal to Briggs' Eq. 4.28 (1969, p. 59), and solving for ΔT. The result is

$$(\Delta T)_c = 0.019582 v_s T s^{1/2}. \qquad \text{(A-11)}$$

If the difference between stack gas temperature and ambient air temperature (ΔT) exceeds or equals $(\Delta T)_c$, the plume rise is assumed to be buoyancy dominated; if ΔT is less than $(\Delta T)_c$, the plume rise is assumed to be momentum dominated.

STABLE: BUOYANCY RISE

For situations where ΔT is greater than or equal to $(\Delta T)_c$, buoyancy is assumed to dominate. The distance to final rise (in kilometers) is determined by the equivalent of a combination of Briggs' Eqs. 48 and 59 (1975, p. 96):

$$x_f = 0.0020715 u(h) s^{-1/2}. \qquad \text{(A-12)}$$

The plume height is determined by the equivalent of Briggs' Eq. 59 (1975, p. 96):

$$H = h' + 2.6\{F/[u(h)s]\}^{1/3}. \qquad \text{(A-13)}$$

The stable buoyancy rise for calm conditions (Briggs, 1975, pp. 81-82) is also evaluated:

$$H = h' + 4F^{1/4} s^{-3/8}. \qquad \text{(A-14)}$$

The lower of the two values obtained from Eqs. A-13 and A-14 is taken as the final effective height.

By setting Eqs. A-13 and A-14 equal to each other and solving for u(h), one can determine the wind speed that yields the same plume rise for the wind conditions (A-13) as does the equation for calm conditions (A-14). This wind speed is

$$u(h) = (2.6/4)^3 F^{1/4} s^{1/8}$$

$$= 0.2746 F^{1/4} s^{1/8}. \qquad \text{(A-15)}$$

For wind speed less than or equal to this value, Eq. A-14 should be used for plume rise; for wind speeds greater than this value, Eq. A-13 should be used.

STABLE: MOMENTUM RISE

When the stack gas temperature is less than the ambient air temperature, it is assumed that the plume rise is dominated by momentum. If ΔT is less than $(\Delta T)_c$ as determined by Eq. A-11, it is also assumed that the plume rise is dominated by momentum. The plume height is calculated from Briggs' Eq. 4.28 (1969, p. 59):

$$H = h' + 1.5\{(v_s^2 d^2 T)/[4T_s u(h)]\}^{1/3} s^{-1/6}. \qquad \text{(A-16)}$$

The equation for unstable or neutral momentum rise (A-9) is also evaluated. The lower result of these two equations is used as the resulting plume height.

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APPENDIX B

LISTING OF FORTRAN SOURCE CODE

INPUFF

The source code listing of INPUFF follows. The program consists of a main module, 8 subroutines, and 2 functions.

```
C     INPUFF   VERSION 84107                                                  PUF0010
C                                                                             PUF0020
C     PROGRAM ABSTRACT:  INPUFF                                               PUF0030
C                                                                             PUF0040
C     INPUFF IS A GAUSSIAN INTEGRATED PUFF MODEL. THE                         PUF0050
C     GAUSSIAN PUFF DIFFUSION EQUATION IS USED TO COMPUTE                     PUF0060
C     THE CONTRIBUTION TO THE CONCENTRATION AT EACH RECEPTOR                  PUF0070
C     FROM EACH PUFF EVERY TIME STEP. COMPUTATIONS IN INPUFF                  PUF0080
C     CAN BE MADE FOR A SINGLE POINT SOURCE AT UP TO 25                       PUF0090
C     RECEPTOR LOCATIONS. IN PRACTICE HOWEVER, THE NUMBER OF                  PUF0100
C     RECEPTORS SHOULD BE KEPT TO A MINIMUM IN THE DEFAULT                    PUF0110
C     MODE THE MODEL ASSUMES A HOMOGENEOUS WIND FIELD.                        PUF0120
C     HOWEVER, THE USER HAS THE OPTION OF SPECIFYING THE                      PUF0130
C     WIND FIELD FOR EACH METEOROLOGICAL PERIOD AT UP TO                      PUF0140
C     100 USER DEFINED GRID LOCATIONS. THREE DISPERSION                       PUF0150
C     ALGORITHMS ARE UTILIZED WITHIN INPUFF FOR DISPERSION                    PUF0160
C     DOWNWIND OF THE SOURCE. THE FIRST TWO ARE PASQUILL'S                    PUF0170
C     SCHEME AS DISCUSSED BY TURNER(1970) AND A DISPERSION                    PUF0180
C     ALGORITHM DISCUSSED BY IRWIN(1983). THIS LATTER SCHEME                  PUF0190
C     IS A SYNTHESIS OF DRAXLER'S(1976) AND CRAMER'S(1976)                    PUF0200
C     IDEAS. THE THIRD DISPERSION SCHEME IS FOR LONG TRAVEL                   PUF0210
C     TIMES IN WHICH THE GROWTH OF THE PUFF BECOMES PROPORTIONAL              PUF0220
C     TO THE SQUARE ROOT OF TIME. A SOFTWARE PLOTTING PACKAGE                 PUF0230
C     IS PROVIDED TO DISPLAY CONCENTRATION VERSUS TIME FOR A                  PUF0240
C     GIVEN RECEPTOR AND THE PUFF TRAJECTORIES AFTER EACH                     PUF0250
C     SIMULATION TIME.                                                        PUF0260
C                                                                             PUF0270
C     REFERANCES:                                                             PUF0280
C                                                                             PUF0290
C     TURNER, D. BRUCE, 1970: WORKBOOK OF ATMOSPHERIC DISPERSION              PUF0300
C     ESTIMATES, OFFICE OF AIR PROGRAMS PUBLICATION NO. AP-26.                PUF0310
C     U. S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE                PUF0320
C     PARK, NC. 84 PP. [NTIS PB 191 482].                                     PUF0330
C                                                                             PUF0340
C     IRWIN, J. S., 1983: ESTIMATING  PLUME DISPERSION--A COMPARISON          PUF0350
C     OF SEVERAL SIGMA SCHEMES. JOURNAL OF CLIMATE AND APPLIED                PUF0360
C     METEOROLOGY, 22, 92-114.                                                PUF0370
C                                                                             PUF0380
C     DRAXLER, R. R., 1976: DETERMINATION OF ATMOSPHERIC                      PUF0390
C     DIFFUSION PARAMETERS, ATMOS. ENVIRON., 10, 99-105.                      PUF0400
C                                                                             PUF0410
C     CRAMER, H. E., 1976: IMPROVED TECHNIQUES FOR MODELING THE               PUF0420
C     DISPERSION OF TALL STACK PLUME. PROCEEDINGS OF THE 7TH                  PUF0430
C     INTERNATIONAL TECHNICAL MEETING ON AIR POLLUTION MODELING               PUF0440
C     AND ITS APPLICATION. N. 51, NATO/CCMS, 731-780.                         PUF0450
C     [NTIS PB 270 799]                                                       PUF0460
C                                                                             PUF0470
C     AUTHOR OF MODEL CODE FOR INPUFF:                                        PUF0480
C                                                                             PUF0490
C     W. B. PETERSEN                                                          PUF0500
C     ON ASSIGNMENT TO THE ENVIRONMENTAL PROTECTION AGENCY FROM               PUF0510
C     THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINSTRATION,                     PUF0520
C     DEPT. OF COMMERCE.                                                      PUF0530
C                                                                             PUF0540
C     PROGRAM SUPPORTED BY:                                                   PUF0550
C                                                                             PUF0560
C     ENVIRONMENTAL OPERATIONS BRANCH                                         PUF0570
C     MAIL DROP 80, EPA.                                                      PUF0580
C     RTP, NC. 27711                                                          PUF0590
C     PHONE (919) 541-4564, FTS 629-4564                                      PUF0600
C                                                                             PUF0610
C     EXTERNAL FILES:                                                         PUF0620
C                                                                             PUF0630
C     THERE ARE TWO OPTIONAL EXTERNAL FILES WHICH MAY BE                      PUF0640
C     UTILIZED IN THE EXECUTION OF INPUFF. IF THE USER SUPPLIES               PUF0650
C     HIS OWN GRIDDED WIND FIELD DATA, THE WIND SPEED AND                     PUF0660
C     DIRECTION ARE READ BY INPUFF FROM UNIT 21. THE FORMAT FOR               PUF0670
C     UNIT 21 IS USER DEFINED. UNIT 22 IS AN OUTPUT FILE GENERATED            PUF0680
C     BY INPUFF IF IP22=1. THIS FILE IS USED BY THE PLOTTING                  PUF0690
C     ROUTINES OR COULD BE USED BY THE USER FOR ADDITIONAL                    PUF0700
C     ANALYSIS OF THE CONCENTRATION ESTIMATES.                                PUF0710
C                                                                             PUF0720
C     ----------------------  FLOW DIAGRAM----------------------              PUF0730
C                                                                             PUF0740
C     INPUFF                                                                  PUF0750
```

```
C        |                                                                    PUF0760
C        |                                                                    PUF0770
C      READ OPTIONS AND INPUT DATA                                          PUF0780
C        |                                                                    PUF0790
C        |                                                                    PUF0800
C        -------  LOOP ON MET. PERIODS                                       PUF0810
C        |      |                                                           PUF0820
C        |      |                                                           PUF0830
C        |      |- PLMRS  (COMPUTE PLUME RISE)                              PUF0840
C        |      |                                                           PUF0850
C        |      |- PGSIG  (COMPUTE SY, SZ FOR PG STABILITY CLASSES)         PUF0860
C        |      |                                                           PUF0870
C        |      |- XVY  (COMPUTE VIRTUAL DISTANCE FOR SY)                   PUF0880
C        |      |                                                           PUF0890
C        |      |- XVZ  (COMPUTE VIRTUAL DISTANCE FOR SZ)                   PUF0900
C        |      |                                                           PUF0910
C        |      |- VTIME  (COMPUTE VIRTUAL TRAVEL TIMES)                    PUF0920
C        |      |   |                                                       PUF0930
C        |      |   |- JSISIG  (COMPUTE SY, SZ BASED ON TRAVEL TIME)        PUF0940
C        |      |                                                           PUF0950
C        |    |--- LOOP ON EACH ISTEP                                       PUF0960
C        |    |   |                                                       PUF0970
C        |    |   |- XVY                                                  PUF0980
C        |    |   |                                                       PUF0990
C        |    |   |- XVZ                                                  PUF1000
C        |    |   |                                                       PUF1010
C        |    |   |- VTIME                                                PUF1020
C        |    |   |                                                       PUF1030
C        |    |   |- ADVECT  (IF IADT NE 0 READ MET. FILE AND COMPUTE     PUF1040
C        |    |   |             GRID COORDINATES OF PUFFS)                PUF1050
C        |    |   |                                                       PUF1060
C        |    |   |- PLMRS                                                PUF1070
C        |    |   |                                                       PUF1080
C        |    |   |-------PROCES                                          PUF1090
C        |    |   |          |                                            PUF1100
C        |    |   |          *                                            PUF1110
C        |    |   |         * *                                           PUF1120
C        |    |   |        *   *                                          PUF1130
C        |    |   |       *  PG *                                         PUF1140
C        |    |   |     NO-* CURVES*                                      PUF1150
C        |    |   |      |  *     *                                       PUF1160
C        |    |   |      |   *   *                                        PUF1170
C        |    |   |      |    * *                                         PUF1180
C        |    |   |      |     *                                          PUF1190
C        |    |   |      |     |                                          PUF1200
C        |    |   |      |    YES                                         PUF1210
C        |    |   |      |     |                                          PUF1220
C        |    |   |      |     |- XVY                                     PUF1230
C        |    |   |      |     |- XVZ                                     PUF1240
C        |    |   |      |     |                                          PUF1250
C        |    |   |      |   BASED ON 6 POSSIBLE VALUES OF KEYP CALL      PUF1260
C        |    |   |      |     |                                          PUF1270
C        |    |   |      |     |- PGSIG                                   PUF1280
C        |    |   |      |     |                                          PUF1290
C        |    |   |      |     |  AND/OR                                  PUF1300
C        |    |   |      |     |                                          PUF1310
C        |    |   |      |     |- LTSIG  (COMPUTE SY AS SQRT(TIME) )      PUF1320
C        |    |   |      |     |                                          PUF1330
C        |    |   |      |-----VTIME                                      PUF1340
C        |    |   |             |                                          PUF1350
C        |    |   |             |                                          PUF1360
C        |    |   |          BASED ON 6 POSSIBLE VALUES OF KEYP CALL      PUF1370
C        |    |   |             |                                          PUF1380
C        |    |   |             |- JSISIG                                  PUF1390
C        |    |   |             |                                          PUF1400
C        |    |   |             |  AND/OR                                  PUF1410
C        |    |   |             |                                          PUF1420
C        |    |   |             |- LTSIG                                   PUF1430
C        |    |   |                                                        PUF1440
C        |    |   |--------CONCEN                                          PUF1450
C        |    |   |        |                                               PUF1460
C        |    |   |    |------|  LOOP ON RECEPTORS                         PUF1470
C        |    |   |    |      |                                            PUF1480
C        |    |   |    |  |---|  PUFF LOOP                                 PUF1490
C        |    |   |    |  |   |                                            PUF1500
```

```
C          |  |   |   |  |   | COMPUTE CONCENTRATIONS EACH ISTEP AND SUM.
C          |  |   |   |  |   |
C          |  |   |   |  |---END OF PUFF LOOP
C          |  |   |   |      |
C          |  |   |   |------END OF RECEPTOR LOOP
C          |  |   |           |
C          |  |   |           | COMBINE PUFFS
C          |  |   |
C          |  |   |
C          |  |---END OF ISTEP LOOP
C          |      |
C          |      |
C          |------END OF MET. LOOP
C          |
C         STOP
C
      INTEGER DISKEY
      DIMENSION CONCT(25),PP(7),ACON(25),CONCI(25),CONCIA(25),
     1TEMP(144),CDIS(144),FRMT(18),ALP(18),TACON(25),FRMAT(18)
      COMMON /XP/ XPUFF(600),YPUFF(600),ZPUFF(600),ITPUFF(600),
     1XDSP(600),QPUFF(600),SY(600),SZ(600),CONC(25),NREC,KEYP(600)
      COMMON /WEA/ WDIR(144),WSPD(144),HL(144),SGTH(144),SGPH(144),
     1PREP(144),XYOP(600),XZOP(600),ITIME,KST(144),STANUM,SW(144),
     2SV(144),UPLM(144)
      COMMON /STA/ QP,HPP,TSP,VSP,DP,VFP,SYOP,SZOP,DH
      COMMON /REC/ XREC(25),YREC(25),ZREC(25),ALPHA,ANHGT
      COMMON /ADVCT/ PDIR(600),PSPD(600),XSWC,YSWC,NUMX,NUMY,DX,DY,FRMAT
      DATA PP/0.07,0.07,0.10,0.15,0.15,0.35,0.55/,MAXPUF/600/
      PI = 3.141593/180.
      NPUFF = 1
      SDIR = 0.
      SSPD = 0.
      READ (5,390) ALP
      READ (5,*) IOPT,IOPS,IADT,IP22,IPCC,IPIC
C         IOPT        STACK DOWNWASH OPTION                (DIMENSIONLESS)
C                     IF IOPT=0 NO DOWNWASH
C         IOPS        UPDATE SOURCE CHARACTERISTICS        (DIMENSIONLESS)
C                     EACH MET. PERIOD. IF IOPS=0 NO UPDATE
C         IADT        USER SUPPLIED WIND FIELD. IF IADT=0  (DIMENSIONLESS)
C                     NO WIND FIELD DATA.
C         IP22        UNIT 22 OUTPUT OPTION. IF IP22=0     (DIMENSIONLESS)
C                     NO OUTPUT TO UNIT 22.
C         IPCC        OPTION TO PRINT OUT PUFF INFORMATION(DIMENSIONLESS)
C                     EACH ITIME. IF IPCC=0 NO PRINT OUT.
C         IPIC        OPTION TO PRINT INTERMEDIATE         (DIMENSIONLESS)
C                     CONCENTRATIONS. IF IPIC=0 NO PRINT OUT.
      IF (IADT.NE.0) READ (5,*) XSWC,YSWC,NUMX,NUMY,DX,DY
C         XSWC        EAST-WEST COORDINATE OF THE SW       (DIMENSIONLESS)
C                     CORNER OF METEOROLOGICAL REGION
C         YSWC        NORTH-SOUTH COORDINATE OF THE SW     (DIMENSIONLESS)
C                     CORNER OF METEOROLOGICAL REGION
C         NUMX        NUMBER OF GRID SQUARES IN EAST-WEST  (DIMENSIONLESS)
C                     DIRECTION
C         NUMY        NUMBER OF GRID SQUARES IN NORTH-     (DIMENSIONLESS)
C                     SOUTH DIRECTION
C         DX          EAST-WEST WIDTH OF GRID SQUARE       (KM)
C         DY          NORTH-SOUTH WIDTH OF GRID SQUARE     (KM)
C         WIND SPEED AND DIRECTION ARE READ IN FOR EACH GRID
C         SQUARE, A ROW AT A TIME, FROM WEST TO EAST (LEFT TO
C         RIGHT). ROWS ARE READ FROM SOUTH TO NORTH (BOTTOM TO
C         TOP).
      IF (IADT.NE.0) READ (5,390) FRMAT
C         FRMAT IS THE FORMAT OF FILE 21 (MET. DATA).
      READ (5,*) NTIME,ITIME,ISTEP,INC,ISIM,ISTTIM,IW,DISKEY,NREC,ANHGT
C         NTIME       NUMBER OF PERIODS OF SIMULATION      (DIMENSIONLESS)
C         ITIME       SIMULATION TIME                      (SECONDS)
C         ISTEP       TIME BETWEEN PUFF RELEASES           (SECONDS)
C                     IF ISTEP IS NEGITIVE A VALUE FOR ISTEP WILL BE
C                     COMPUTED BASED ON THE STABILITY CLASS, WIND SPEED
C                     AND MINIMUM DISTANCE FROM SOURCE TO RECEPTOR(CDIS).
C         INC         SAMPLING TIME FOR CONCENTRATIONS     (SECONDS)
C         ISIM        TIME TO START CONCENTRATION          (SECONDS)
C                     CALCULATIONS
C         ISTTIM      A  MULTIPLE OF ISTEP FOR PUFF        (DIMENSIONLESS)
C                     COMBINATIONS.
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226.   C          IW          UNIT NUMBER FOR WRITE STATEMENTS     (DIMENSIONLESS) PUF2260
227.   C          DISKEY      DISPERSION OPTION                    (DIMENSIONLESS) PUF2270
228.   C                      DISKEY=1  FOR PG CURVES                              PUF2280
229.   C                      DISKEY=2  FOR TRAVEL TIME CURVES                     PUF2290
230.   C          NREC        NUMBER OF RECEPTORS                  (DIMENSIONLESS) PUF2300
231.   C          ANHGT       ANEMOMETER HEIGHT                    (M)             PUF2310
232.            READ (5,*) XGRID,YGRID,XSIZE,YSIZE,STANUM,ALPHA,SYMAX              PUF2320
233.   C          XGRID       EAST-WEST COORDINATE OF              (KM)            PUF2330
234.   C                      S.W. CORNER OF MODEL REGION                          PUF2340
235.   C          YGRID       NORTH-SOUTH COORDINATE OF S.W.       (KM)            PUF2350
236.   C                      CORNER OF MODEL REGION                               PUF2360
237.   C          XSIZE       EAST-WEST SIZE OF MODEL REGION       (KM)            PUF2370
238.   C          YSIZE       NORTH-SOUTH SIZE OF MODEL REGION     (KM)            PUF2380
239.   C          STANUM      THE NUMBER OF SIGMA Y'S THE PUFF IS  (DIMENSIONLESS) PUF2390
240.   C                      FROM THE RECEPTOR SUCH THAT NO                       PUF2400
241.   C                      CONCENTRATION ESTIMATE IS MADE                       PUF2410
242.   C          ALPHA       FRACTION OF CROSSWIND DISPERSION     (DIMENSIONLESS) PUF2420
243.   C                      FOR PUFF COMBINATION                                 PUF2430
244.   C          SYMAX       MAXIMUM SIZE OF SIGMA Y BEFOR GOING  (M)             PUF2440
245.   C                      TO LTSIG ROUTINE.                                    PUF2450
246.            READ (5,*) XSORC,YSORC,QP,HPP,TSP,DP,VSP,VFP,SYOP,SZOP,SDIR,SSPD   PUF2460
247.   C          XSORC       X COORDINATE OF SOURCE               (KM)            PUF2470
248.   C          YSORC       Y COORDINATE OF SOURCE               (KM)            PUF2480
249.   C          QP          EMISSION RATE                        (G/SEC)         PUF2490
250.   C          HPP         HEIGHT OF RELEASE                    (M)             PUF2500
251.   C          TSP         STACK GAS TEMPERATURE                (KELVIN)        PUF2510
252.   C          DP          STACK DIAMETER                       (M)             PUF2520
253.   C          VSP         STACK GAS VELOCITY                   (M/SEC)         PUF2530
254.   C          VFP         STACK GAS VOLUME FLOW                (M**3/SEC)      PUF2540
255.   C          SYOP        INITIAL SIGMA Y                      (M)             PUF2550
256.   C          SZOP        INITIAL SIGMA Z                      (M)             PUF2560
257.   C          SDIR        SOURCE DIRECTION                     (DEGREES)       PUF2570
258.   C          SSPD        SOURCE SPEED                         (M/SEC)         PUF2580
259.            READ (5,*) (XREC(I),YREC(I),ZREC(I),I=1,NREC)                      PUF2590
260.   C          XREC        X COORDINATE OF RECCEPTOR            (KM)            PUF2600
261.   C          YREC        Y COORDINATE OF RECEPTOR             (KM)            PUF2610
262.   C          ZREC        Z COORDINATE OF RECEPTOR             (M)             PUF2620
263.            READ (5,390) FRMT                                                  PUF2630
264.   C          FORMAT FOR METEOROLOGICAL DATA                                   PUF2640
265.   C                                                                           PUF2650
266.            READ (5,FRMT) (WDIR(I),WSPD(I),HL(I),KST(I),SGPH(I),SGTH(I),      PUF2660
267.           1TEMP(I),CDIS(I),I=1,NTIME)                                         PUF2670
268.   C          WDIR        WIND DIRECTION                       (DEGREES)       PUF2680
269.   C          WSPD        WIND SPEED                           (M/SEC)         PUF2690
270.   C          HL          MIXING HEIGHT                        (M)             PUF2700
271.   C          KST         STABILITY CLASS                      (DIMENSIONLESS) PUF2710
272.   C          SGPH        SIGMA PHI                            (RADIANS)       PUF2720
273.   C          SGTH        SIGMA THETA                          (RADIANS)       PUF2730
274.   C          TEMP        AIR TEMPERTURE                       (K)             PUF2740
275.   C          CDIS        MINIMUM DISTANCE SOURCE TO RECEPTOR  (KM)            PUF2750
276.   C                                                                           PUF2760
277.            IF(ALPHA.LT.0.) ALPHA=1.0                                          PUF2770
278.            IF(STANUM.LT.0.) STANUM=3.0                                        PUF2780
279.            IF(ISTTIM.LT.0) ISTTIM=3                                           PUF2790
280.            ISTSA = ISTEP                                                      PUF2800
281.            SYTT = SYOP                                                        PUF2810
282.            SZTT = SZOP                                                        PUF2820
283.            DO 5 J=1,25                                                        PUF2830
1          284.              TACON(J) = 0.                                         PUF2840
1          285.    5       CONTINUE                                               PUF2850
286.            WRITE (IW,370) ALP                                                 PUF2860
287.            WRITE (IW,380)                                                     PUF2870
288.            WRITE (IW,400) IOPT,IOPS,IADT,IP22,IPCC,IPIC                       PUF2880
289.            WRITE (IW,410) ISIM,ISTTIM,STANUM,ALPHA,SYMAX,ANHGT                PUF2890
290.            XGRID2 = XGRID + XSIZE                                             PUF2900
291.            YGRID2 = YGRID + YSIZE                                             PUF2910
292.            TD = 0.                                                            PUF2920
293.            IF (IP22.NE.0) WRITE (22) NTIME,ITIME,NREC                         PUF2930
294.   C          THE FOLLOWING INFORMATION IS WRITTEN TO UNIT 22 IF               PUF2940
295.   C           IP22 .NE. 0.                                                    PUF2950
296.   C          WRITE  NTIME,ITIME,NREC                                          PUF2960
297.   C          WRITE  XREC,YREC,ZREC                                            PUF2970
298.   C            ( 1 WRITE FOR EACH OF NREC NUMBER OF RECEPTORS)                PUF2980
299.   C          WRITE  IT,ISTEP                  -----|                          PUF2990
300.   C          WRITE  ITM,(CONC(I),I=1,NREC)        NTIME NUMBER                PUF3000
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      C           (1 WRITE EACH ISTEP)                OF WRITES                PUF3010
      C         WRITE  NPUFF (# OF PUFFS)               |                      PUF3020
      C         WRITE  XPUFF,YPUFF,ZPUFF,SY,SZ          |                      PUF3030
      C           (NPUFF NUMBER OF WRITES)        -------|                      PUF3040
      C                                                                          PUF3050
      C         THE FOLLOWING CODE CAN BE USED TO READ UNIT 22.                  PUF3060
      C         READ(22) NTIME,ITIME,NREC                                        PUF3070
      C            DO 10 I=1,NREC                                                PUF3080
      C         10 READ(22) XREC(I),YREC(I),ZREC(I)                              PUF3090
      C         20 READ(22) IT,ISTEP                                             PUF3100
      C         30 READ(22) ITM,(CONC(K),K=1,NREC)                               PUF3110
      C            IF (ITM.LT.IT*ITIME) GO TO 30                                 PUF3120
      C            READ(22) NPUFF                                                PUF3130
      C            DO 40 NP=1,NPUFF                                              PUF3140
      C         40 READ(22) XPUFF(NP),YPUFF(NP),ZPUFF(NP),SY(NP),SZ(NP)          PUF3150
      C            IF (IT.LT.NTIME) GO TO 20                                     PUF3160
            IF (IP22.EQ.0) GO TO 20                                              PUF3170
            DO 10 J=1,NREC                                                       PUF3180
1           WRITE (22) XREC(J),YREC(J),ZREC(J)                                   PUF3190
1     10    CONTINUE                                                             PUF3200
      20    CONTINUE                                                             PUF3210
      C         BEGIN DO LOOP FOR MET. PERIODS                                   PUF3220
            DO 360 IT=1,NTIME                                                    PUF3230
1           IF (IT.EQ.1) GO TO 30                                                PUF3240
1           IF (IOPS.NE.0) READ (5,*) QP,HPP,TSP,DP,VSP,VFP,SYOP,                PUF3250
1          1  SZOP,SDIR,SSPD                                                    PUF3260
1     C         IF IOPS .NE. 0  READ NEW SOURCE DATA.                          PUF3270
1     30    CONTINUE                                                             PUF3280
1           IF (IOPS.EQ.0) SYOP = SYTT                                           PUF3290
1           IF (IOPS.EQ.0) SZOP = SZTT                                           PUF3300
1           ISTEP = ISTSA                                                        PUF3310
1           IF (IT.EQ.1) GO TO 40                                                PUF3320
1           IF (HL(IT).LT.HL(IT-1).AND.KST(IT).LE.4) HL(IT) = HL(IT-1)           PUF3330
1     C         UNDER NEUTRAL OR UNSTABLE CONDITIONS THE MIXED LAYER             PUF3340
1     C          CANNOT DECREASE WITH TIME.                                      PUF3350
1     40    CONTINUE                                                             PUF3360
1           KS = KST(IT)                                                         PUF3370
1           PREP(IT) = PP(KS)                                                    PUF3380
1           TD = ITIME                                                           PUF3390
1           CALL PLMRS (KS,WSPD(IT),TEMP(IT),PREP(IT),IOPT,ANHGT,DH,HE)          PUF3400
1     C         DH=PLUME RISE                                                    PUF3410
1     C         HE=EFFECTIVE STACK HEIGHT                                        PUF3420
1           PHGT = HE                                                            PUF3430
1     C         EXTRAPOLATE WIND SPEED UP TO PLUME HEIGHT OR 200 M.              PUF3440
1     C          WHICH EVER IS LOWER                                             PUF3450
1           IF (HE.GT.200.) PHGT = 200.                                          PUF3460
1           USCAL = (PHGT/ANHGT)**PREP(IT)                                       PUF3470
1           IF (ANHGT.GT.PHGT) USCAL = 1.                                        PUF3480
1     C         ANEMOMETER HEIGHT SHOULD BE NEAR THE SURFACE. IF                 PUF3490
1     C          THE WIND SPEEDS GIVEN ARE APPROPRIATE FOR HEIGHTS               PUF3500
1     C          ABOVE THE PLUME HEIGHT NO EXTRAPOLATIONS ARE                    PUF3510
1     C          PERFORMED.                                                      PUF3520
1           UPLM(IT) = WSPD(IT)*USCAL                                            PUF3530
1           SV(IT)   = SGTH(IT)*UPLM(IT)                                         PUF3540
1           SW(IT)   = SGPH(IT)*UPLM(IT)                                         PUF3550
1           USPD     = -UPLM(IT)*SIN(WDIR(IT)*PI)                                PUF3560
1           VSPD     = -UPLM(IT)*COS(WDIR(IT)*PI)                                PUF3570
1           XSPD     = SSPD*SIN(SDIR*PI)                                         PUF3580
1           YSPD     = SSPD*COS(SDIR*PI)                                         PUF3590
1     C         USPD U COMPONENT OF WIND.                                        PUF3600
1     C         VSPD V COMPONENT OF WIND.                                        PUF3610
1     C         XSPD X COMPONENT OF SOURCE SPEED.                                PUF3620
1     C         YSPD Y COMPONENT OF SOURCE SPEED.                                PUF3630
1           CALL PGSIG (CDIS,CDIS,KS,SYT,SZT)                                    PUF3640
1           DPLM = SQRT((USPD-XSPD)**2 + (VSPD-YSPD)**2)                         PUF3650
1           IF (DPLM.LT.UPLM(IT)) DPLM = UPLM(IT)                                PUF3660
1           SRT = (2.*SYT)/DPLM                                                  PUF3670
1           ISRT = SRT                                                           PUF3680
1           IF (ISTEP.GT.0) GO TO 100                                            PUF3690
1     C         IF ISTEP IS NEGITIVE A VALUE FOR ISTEP WILL BE                   PUF3700
1     C          COMPUTED BASED ON THE STABILITY CLASS, WIND SPEED               PUF3710
1     C          AND MINIMUM DISTANCE FROM SOURCE TO RECEPTOR(CDIS).             PUF3720
1           IF (ISRT.GE.INC) GO TO 90                                            PUF3730
1           IF (ISRT.LE.1) GO TO 80                                              PUF3740
1           DO 60 I=1,ISRT                                                       PUF3750
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2      376.                IRR = ISRT - I + 1                                    PUF3760
2      377.                IR = MOD(INC,IRR)                                     PUF3770
2      378.                IF (IR.EQ.0) GO TO 70                                 PUF3780
2      379.    60        CONTINUE                                                PUF3790
1      380.    70        ISTEP = IRR                                             PUF3800
1      381.              GO TO 100                                               PUF3810
1      382.    80        ISTEP = 1                                               PUF3820
1      383.              GO TO 100                                               PUF3830
1      384.    90        ISTEP = INC/2                                           PUF3840
1      385.    100     CONTINUE                                                  PUF3850
1      386.            IF (IT.NE.1) GO TO 110                                    PUF3860
1      387.               ITPUFF(1) = 0                                          PUF3870
1      388.               XPUFF(1)  = XSORC*1000.                                PUF3880
1      389.               YPUFF(1)  = YSORC*1000.                                PUF3890
1      390.               ZPUFF(1)  = HE                                         PUF3900
1      391.               KEYP(1)   = 1                                          PUF3910
1      392.    C           KEYP(NPUFF)=1 PUFF BELOW MIXED LAYER AND SHORT RANGE  PUF3920
1      393.    C           KEYP(NPUFF)=2 USE SIGMAS APPROPRIATE FOR LONG TRAVEL TIMES.  PUF3930
1      394.    C           KEYP(NPUFF)=3 PUFF ABOVE MIXED LAYER                  PUF3940
1      395.    C           KEYP(NPUFF)=4 PUFF WELL MIXED AND SHORT RANGE         PUF3950
1      396.    C           KEYP(NPUFF)=5 PUFF ABOVE MIXED LAYER AND LONG RANGE   PUF3960
1      397.    C           KEYP(NPUFF)=6 LONG TRAVEL TIME AND WELL MIXED.        PUF3970
1      398.               SY(1) = SYOP                                           PUF3980
1      399.               SZ(1) = SZOP                                           PUF3990
1      400.               IF (ZPUFF(1).GT.HL(IT)) KEYP(1) = 3                    PUF4000
1      401.    C           QPUFF EMISSIONS DURING PERIOD ISTEP.                  PUF4010
1      402.    C           XPUFF,YPUFF,ZPUFF PUFF COOR.                          PUF4020
1      403.               QPUFF(1) = QP*ISTEP                                    PUF4030
1      404.               KS = KST(IT)                                           PUF4040
1      405.               IF (KEYP(1).EQ.3) KS = 7                               PUF4050
1      406.    C           COMPUTE VIRTUAL DISTANCE                              PUF4060
1      407.               XYOP(1) = XVY(SYOP,KS)                                 PUF4070
1      408.               XZOP(1) = XVZ(SZOP,KS)                                 PUF4080
1      409.               XDSP(1) = 0.                                           PUF4090
1      410.               IF (DISKEY.EQ.1) GO TO 110                             PUF4100
1      411.               IF (KEYP(1).EQ.3.OR.KEYP(1).EQ.5) KS = 7               PUF4110
1      412.    C           COMPUTE VIRTUAL TIME                                  PUF4120
1      413.               CALL VTIME (KEYP(1),IT,KS,SY(1),SZ(1),XYOP(1),XZOP(1))  PUF4130
1      414.    110     CONTINUE                                                  PUF4140
1      415.            ITMS = 0                                                  PUF4150
1      416.            WRITE (IW,420) ITPUFF(NPUFF),QP,HPP,TSP,VSP,DP,VFP,XSORC,YSORC,  PUF4160
1      417.           1SSPD,SDIR,HE                                              PUF4170
1      418.            WRITE (IW,430) WDIR(IT),WSPD(IT),HL(IT),PREP(IT),KST(IT),UPLM(IT),  PUF4180
1      419.           1TEMP(IT),SYOP,SZOP,SGTH(IT),SGPH(IT)                      PUF4190
1      420.            ISTRP = IT*ITIME - ITIME                                  PUF4200
1      421.            ISTOP = IT*ITIME                                          PUF4210
1      422.            WRITE (IW,440) ISTRP,ISTOP,ITIME,ISTEP,CDIS(IT),DISKEY    PUF4220
1      423.            DO 120 I=1,NREC                                           PUF4230
1      424.    C           ZERO CONCENTRATION ARRAYS.                            PUF4240
2      425.               CONCT(I) = 0.                                          PUF4250
2      426.               CONC(I)  = 0.                                          PUF4260
2      427.               CONCI(I) = 0.                                          PUF4270
2      428.    120     CONTINUE                                                  PUF4280
1      429.            IST10 = ISTTIM*ISTEP                                      PUF4290
1      430.            IF (IP22.NE.0) WRITE (22) IT,ISTEP                        PUF4300
1      431.    C           BEGIN DO LOOP FOR ISTEP WITHIN LOOP FOR MET. PERIOD   PUF4310
1      432.            DO 350 I=ISTEP,ITIME,ISTEP                                PUF4320
2      433.            ITRAV = I                                                 PUF4330
2      434.            NPUFF = NPUFF + 1                                         PUF4340
2      435.            IF (NPUFF.GT.MAXPUF) STOP 100                             PUF4350
2      436.            XSORC = XSORC + (XSPD*ISTEP)/1000.                        PUF4360
2      437.            YSORC = YSORC + (YSPD*ISTEP)/1000.                        PUF4370
2      438.    C           ADVECT SOURCE COOR.                                   PUF4380
2      439.            XPUFF(NPUFF) = XSORC*1000.                                PUF4390
2      440.            YPUFF(NPUFF) = YSORC*1000.                                PUF4400
2      441.    C           XPUFF,YPUFF  NEW PUFF COOR.                           PUF4410
2      442.            ZPUFF(NPUFF) = HE                                         PUF4420
2      443.            QPUFF(NPUFF) = QP*ISTEP                                   PUF4430
2      444.            KEYP(NPUFF) = 1                                           PUF4440
2      445.            SY(NPUFF) = SYOP                                          PUF4450
2      446.            SZ(NPUFF) = SZOP                                          PUF4460
2      447.            IF (ZPUFF(NPUFF).GT.HL(IT)) KEYP(NPUFF) = 3               PUF4470
2      448.    C           QPUFF IS EMISSION RATE OF CURRENT PUFF.               PUF4480
2      449.            KS = KST(IT)                                              PUF4490
2      450.            IF (KEYP(NPUFF).EQ.3) KS = 7                              PUF4500
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2      451.          XYOP(NPUFF) = XVY(SYOP,KS)                                    PUF4510
2      452.          XZOP(NPUFF) = XVZ(SZOP,KS)                                    PUF4520
2      453.          IF (DISKEY.EQ.1) GO TO 130                                    PUF4530
2      454.             IF (KEYP(NPUFF).EQ.3.OR.KEYP(NPUFF).EQ.5) KS = 7           PUF4540
2      455.             CALL VTIME (KEYP(NPUFF),IT,KS,SY(NPUFF),SZ(NPUFF),         PUF4550
2      456.           1    XYOP(NPUFF),XZOP(NPUFF))                               PUF4560
2      457.   130    XDSP(NPUFF) = 0.                                              PUF4570
2      458.          ITM = ITM + ISTEP                                             PUF4580
2      459.          ITPUFF(NPUFF) = ITM                                           PUF4590
2      460.   C          ITPUFF TIME OF RELEASE OF CURRENT PUFF.                   PUF4600
2      461.          NN = NPUFF - 1                                                PUF4610
2      462.   C          ADVECT ALL PREVIOUS PUFFS.                               PUF4620
2      463.          IF (IADT.EQ.0) GO TO 140                                      PUF4630
2      464.             CALL ADVECT (NPUFF,ITRAV,ISTEP)                            PUF4640
2      465.             IF (XSPD.LT.0.01) GO TO 140                                PUF4650
2      466.             UZP = PSPD(NPUFF)                                          PUF4660
2      467.             IF (ABS(WSPD(IT)-UZP).LE.0.1) GO TO 140                    PUF4670
2      468.             CALL PLMRS(KS,UZP,TEMP(IT),PREP(IT),IOPT,ANHGT,DH,HE)      PUF4680
2      469.             ZPUFF(NPUFF) = HE                                          PUF4690
2      470.             WSPD(IT) = UZP                                             PUF4700
2      471.             PHGT = HE                                                  PUF4710
2      472.             IF (HE.GT.200.) PHGT = 200.                                PUF4720
2      473.             USCAL = (PHGT/ANHGT)**PREP(IT)                             PUF4730
2      474.             IF (ANHGT.GT.PHGT) USCAL = 1.                              PUF4740
2      475.             UPLM(IT) = WSPD(IT)*USCAL                                  PUF4750
2      476.   140    CONTINUE                                                      PUF4760
2      477.          DO 160 J=1,NN                                                 PUF4770
3      478.             L = NN + 1 - J                                             PUF4780
3      479.             IF (IADT.EQ.0) GO TO 150                                   PUF4790
3      480.                USPD = -SIN(PDIR(L)*PI)*PSPD(L)*USCAL                   PUF4800
3      481.                VSPD = -COS(PDIR(L)*PI)*PSPD(L)*USCAL                   PUF4810
3      482.   150       CONTINUE                                                   PUF4820
3      483.             XPUFF(L) = XPUFF(L) + USPD*ISTEP                           PUF4830
3      484.             YPUFF(L) = YPUFF(L) + VSPD*ISTEP                           PUF4840
3      485.   160    CONTINUE                                                      PUF4850
2      486.          CALL PROCES (NPUFF,ISTEP,DISKEY,IT,ITRAV,SYMAX,IAVT)          PUF4860
2      487.          IF (ITM.LT.ISIM) GO TO 170                                    PUF4870
2      488.   C          CONC. FROM THE PUFFS AT TIME=ITPUFF.                     PUF4880
2      489.             CALL CONCEN (NPUFF,IST10,I)                                PUF4890
2      490.             IF (IP22.NE.0) WRITE (22) ITM,(CONC(IJP),IJP=1,NREC)       PUF4900
2      491.   170    CONTINUE                                                      PUF4910
2      492.          IRM = MOD(I,IST10)                                            PUF4920
2      493.          IF (IRM.NE.0) GO TO 210                                       PUF4930
2      494.             NPU = NPUFF                                                PUF4940
2      495.             DO 180 KPF=1,NPU                                           PUF4950
3      495.5               IF (QPUFF(KPF).LE.0.) KEYP(KPF) = -1                    PUF4955
3      496.                XTG = XPUFF(KPF)/1000.                                  PUF4960
3      497.                YTG = YPUFF(KPF)/1000.                                  PUF4970
3      498.                IF (XTG.LT.XGRID.OR.XTG.GT.XGRID2.OR.                   PUF4980
3      499.           1        YTG.LT.YGRID.OR.YTG.GT.YGRID2) KEYP(KPF) = -1       PUF4990
3      500.   180       CONTINUE                                                   PUF5000
2      501.             L = 0                                                      PUF5010
2      502.             DO 190 KPF = 1,NPU                                         PUF5020
2      503.   C             COMPUTE NUMBER OF PUFFS AFTER PUFF ELIMINATION.      PUF5030
3      504.                IF (KEYP(KPF).LT.0) GO TO 190                           PUF5040
3      505.                L          = L + 1                                      PUF5050
3      506.                XPUFF(L)   = XPUFF(KPF)                                 PUF5060
3      507.                YPUFF(L)   = YPUFF(KPF)                                 PUF5070
3      508.                ZPUFF(L)   = ZPUFF(KPF)                                 PUF5080
3      509.                QPUFF(L)   = QPUFF(KPF)                                 PUF5090
3      510.                ITPUFF(L)  = ITPUFF(KPF)                                PUF5100
3      511.                SY(L)      = SY(KPF)                                    PUF5110
3      512.                SZ(L)      = SZ(KPF)                                    PUF5120
3      513.                XYOP(L)    = XYOP(KPF)                                  PUF5130
3      514.                XZOP(L)    = XZOP(KPF)                                  PUF5140
3      515.                KEYP(L)    = KEYP(KPF)                                  PUF5150
3      516.                XDSP(L)    = XDSP(KPF)                                  PUF5160
3      517.   190       CONTINUE                                                   PUF5170
2      518.             NPUFF = L                                                  PUF5180
2      519.   210    CONTINUE                                                      PUF5190
2      520.   C          SUMMING CONC. FOR SAMPLING PERIOD, I.E. 1 HR.             PUF5200
2      521.          DO 220 L=1,NREC                                               PUF5210
3      522.             CONCT(L) = CONCT(L) + CONC(L)                              PUF5220
3      523.   220    CONTINUE                                                      PUF5230
3      524.   C          SUMMING CONC. FOR INTER. SAMPLING PERIODS,I.E. 5 MIN.     PUF5240
2      525.          DO 230 L=1,NREC                                               PUF5250
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3      526.                CONCI(L) = CONCI(L) + CONC(L)                                    PUF5260
3      527.    230      CONTINUE                                                           PUF5270
2      528.             IF (I.NE.ITIME) GO TO 290                                          PUF5280
2      529.                IF (IP22.NE.0) WRITE (22) NPUFF                                 PUF5290
2      530.                IF (IP22.EQ.0) GO TO 250                                        PUF5300
2      531.                   DO 240 INPF=1,NPUFF                                          PUF5310
3      532.                      WRITE (22) XPUFF(INPF),YPUFF(INPF),ZPUFF(INPF),           PUF5320
3      533.          1           SY(INPF),SZ(INPF)                                        PUF5330
3      534.    240            CONTINUE                                                    PUF5340
2      535.    250         CONTINUE                                                       PUF5350
2      536.                IF (IPCC.EQ.0) GO TO 270                                        PUF5360
2      537.                   WRITE (IW,450)                                               PUF5370
2      538.                   DO 260 IPR=1,NPUFF                                           PUF5380
3      539.                      WRITE (IW,460) IPR,XPUFF(IPR),YPUFF(IPR),                 PUF5390
3      540.          1           ZPUFF(IPR),ITPUFF(IPR),QPUFF(IPR),SY(IPR),               PUF5400
3      541.          2           SZ(IPR),KEYP(IPR)                                        PUF5410
3      542.    260            CONTINUE                                                    PUF5420
2      543.    270         CONTINUE                                                       PUF5430
2      544.    C            IF I=ITIME  END OF SIMULATION PERIOD.                         PUF5440
2      545.                DIV = FLOAT(ITIME)/FLOAT(ISTEP)                                PUF5450
2      546.    C            AVG. CONC. FOR SAMPLING TIME.                                 PUF5460
2      547.                DO 280 L=1,NREC                                                PUF5470
3      548.                   ACON(L) = CONCT(L)/DIV                                      PUF5480
3      549.                   TACON(L) = TACON(L) + ACON(L)                               PUF5490
3      550.    280            CONTINUE                                                    PUF5500
2      551.    290      CONTINUE                                                          PUF5510
2      552.             IRM = MOD(ITM,INC)                                                PUF5520
2      553.             IF (IRM.NE.0) GO TO 350                                           PUF5530
2      554.    C            IF IRM=0 END OF INTER. SAMPLING PERIOD, I.E. 5 MIN.           PUF5540
2      555.                DIV = FLOAT(INC)/FLOAT(ISTEP)                                  PUF5550
2      556.    C            AVG. CONC. AT END OF INTER. SAMPLING PERIOD.                  PUF5560
2      557.                DO 300 J=1,NREC                                                PUF5570
3      558.                   CONCIA(J) = CONCI(J)/DIV                                    PUF5580
3      559.    300         CONTINUE                                                       PUF5590
3      560.    C            ZERO CONC. ARRAYS FOR INTER. SAMPLING TIMES.                  PUF5600
2      561.                DO 310 L=1,NREC                                                PUF5610
3      562.                   CONCI(L) = 0.                                               PUF5620
3      563.    310         CONTINUE                                                       PUF5630
2      564.                IF (IPIC.EQ.0) GO TO 330                                       PUF5640
2      565.                   ITMM = ITM - INC                                            PUF5650
2      566.                   WRITE (IW,470) INC,ITMM,ITM                                 PUF5660
2      567.                   DO 320 J=1,NREC                                             PUF5670
3      568.                      WRITE (IW,480) XREC(J),YREC(J),ZREC(J),CONCIA(J)         PUF5680
3      569.    320            CONTINUE                                                    PUF5690
2      570.    330         CONTINUE                                                       PUF5700
2      571.                IF (I.NE.ITIME) GO TO 350                                      PUF5710
2      572.                   WRITE (IW,490) ITIME,ISTRP,ISTOP                            PUF5720
2      573.                   DO 340 J=1,NREC                                             PUF5730
3      574.                      WRITE (IW,480) XREC(J),YREC(J),ZREC(J),ACON(J)           PUF5740
3      575.    340            CONTINUE                                                    PUF5750
2      576.    350      CONTINUE                                                          PUF5760
2      577.    C            END LOOP OVER ISTEP                                           PUF5770
1      578.    360      CONTINUE                                                          PUF5780
1      579.    C            END LOOP OVER MET. PERIOD                                     PUF5790
       580.             DIV = FLOAT(NTIME)                                                PUF5800
       581.             DO 365 J=1,NREC                                                   PUF5810
1      582.                TACON(J) = TACON(J)/DIV                                        PUF5820
1      583.    365      CONTINUE                                                          PUF5830
       584.             TOTT = (NTIME*ITIME)/3600.                                        PUF5840
       585.             WRITE(IW,500) TOTT                                                PUF5850
       586.             DO 367 J=1,NREC                                                   PUF5860
1      587.                WRITE(IW,480) XREC(J),YREC(J),ZREC(J),TACON(J)                 PUF5870
1      588.    367      CONTINUE                                                          PUF5880
       589.             STOP                                                              PUF5890
       590.    370      FORMAT ('1',3X,18A4)                                              PUF5900
       591.    380      FORMAT (60X,'VERSION 84107')                                      PUF5910
       592.    390      FORMAT (18A4)                                                     PUF5920
       593.    400      FORMAT (3X,'O P T I O N S ',10X,'A "1" INDICATES THAT THE OPTION'/ PUF5930
       594.            1T34,'HAS BEEN EXERCISED'//3X,'STACK DOWNWASH',T33,I3/3X,         PUF5940
       595.            2'UPDATE SOURCE DATA',T33,I3/3X,                                  PUF5950
       596.            3'USER SUPPLIED WIND FIELD',T33,I3/3X,'UNIT 22 OUTPUT OPTION',T33, PUF5960
       597.            4I3/3X,'PRINT PUFF INFORMATION',T33,I3/3X,'INTERMEDIATE CONCENTRA', PUF5970
       598.            5'TIONS',T33,I3//)                                                PUF5980
       599.    410      FORMAT (3X,'I N P U T   P A R A M E T E R S '//3X,'ISIM=',I6/3X,   PUF5990
       600.            1'ISTTIM=',I6/3X,'STANUM=',F5.2/3X,'ALPHA=',F5.2/3X,'SYMAX=',F9.1/ PUF6000
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      23X,'ANHGT=',F5.1//)                                                    PUF6010
  420  FORMAT ('1 * * *  S O U R C E  I N F O R M A T I O N  * * *'//         PUF6020
     1T2,'SOURCE',T11,'STACK',T21,'STACK',T31,'STACK GAS',T42,'STACK',       PUF6030
     2T51,'VOLUME',T62,'COORDINATES AT TIME ',I5,T90,'SOURCE',T100,'SO',     PUF6040
     3'URCE',T115,'PLUME'/T2,'STRENGTH',T11,'HEIGHT',T21,'TEMP.',T31,        PUF6050
     4'VELOCITY',T41,'DIAMETER',T52,'FLOW',T64,'EAST',T77,'NORTH',T90,       PUF6060
     5'SPEED',T100,'DIRECTION',T115,'HEIGHT'/T3,'(G/SEC)',T12,'(M)',T20,     PUF6070
     6'(DEG-K)',T32,'(M/SEC)',T43,'(M)',T50,'(M**3/SEC)',T64,'(KM)',T78,     PUF6080
     7'(KM)',T90,'(M/SEC)',T100,'(DEG)',T116,'(M)'//T2,E8.3,T11,F6.2,        PUF6090
     8T21,F7.3,T32,F7.3,T41,F6.3,T51,F8.3,T61,F9.3,T75,F9.3,T91,F7.3,        PUF6100
     9T101,F5.1,T115,F7.2/)                                                  PUF6110
  430  FORMAT (///' * * *  M E T E O R O L O G Y  * * *'//T76,'INITIA',       PUF6120
     1'L SIGMAS'/T2,'WIND DIR.',T14,'WIND SPD.',T25,'MIXING HGT.',T39,       PUF6130
     2'PROF.EP',T50,'STABILITY',T60,' U PLUME',T70,'TEMP',T79,'(R)   (',     PUF6140
     3'Z)',T91,'SIGMA TH.',T102,'SIGMA PH.'/T4,'(DEG)',T15,'(M/SEC)',       PUF6150
     4T28,'(M)',T39,'(DIMEN)',T50,'(CLASS)',T61,'(M/SEC)',T71,'(K)',T82,     PUF6160
     5'(M)',T92,'(RAD.)',T104,'(RAD.)'//T3,F5.1,T16,F6.3,T27,F5.0,T39,       PUF6170
     6F7.3,T50,I4,T60,F7.3,T70,F5.1,T77,F5.1,T83,F5.1,T91,F6.4,T102,         PUF6180
     7F6.4/)                                                                 PUF6190
  440  FORMAT (T6,'SIMULATION PERIOD',T26,'SIMULATION TIME',T45,'PUFF R',     PUF6200
     1'ELEASE RATE',T65,'SOURCE RECEPTOR DISTANCE',T95,'DISPERSION'/T3,      PUF6210
     2'START (SEC)  STOP (SEC)',T31,'(SEC)',T51,'(SEC)',T75,'(KM)',T98,     PUF6220
     3'TYPE'/T3,I6,T16,I6,T32,I4,T51,I4,T72,F8.2,T100,I1//)                  PUF6230
  450  FORMAT (///' PUFF#',T15,'X',T26,'Y',T37,'Z',T44,'TIME',T54,'TOTA',     PUF6240
     1'L Q',T67,'SY',T77,'SZ',T85,'KEYP'/)                                   PUF6250
  460  FORMAT (2X,I4,3X,3(F10.3,1X),I6,3X,F10.2,2F10.3,T85,I1)                PUF6260
  470  FORMAT (///2X,I6,' SEC',' AVG. CONCENTRATION AT RECEPTORS DURING',     PUF6270
     1' INTERMEDIATE PERIOD ',I6,' TO ',I6,' SECONDS'//10X,'RECEPTORS'/      PUF6280
     2T5,'X',T15,'Y',T25,'Z',T35,'CONCENTRATION (G/M**3)'/)                  PUF6290
  480  FORMAT (T2,F9.3,T12,F9.3,T22,F9.3,T37,1PE9.3)                          PUF6300
  490  FORMAT (///5X,I6,' SEC AVG. CONCENTRATION AT RECEPTORS FOR SIMUL',     PUF6310
     1'ATION PERIOD ',I6,' TO ',I6,' SECONDS'//10X,'RECEPTORS'/T5,'X',       PUF6320
     2T15,'Y',T25,'Z',T35,'CONCENTRATION (G/M**3)'/)                         PUF6330
  500  FORMAT('1  ',41('* ')/2X,F6.2,' HR AVG. CONCENTRATION AT RECEPTO',     PUF6340
     1'RS FOR ALL SIMULATION PERIODS'//10X,'RECEPTORS'/T5,'X',T15,'Y',       PUF6350
     2T25,'Z',T35,'CONCENTRATION (G/M**3)'/)                                 PUF6360
       END                                                                   PUF6370
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      SUBROUTINE ADVECT (NPUFF,ITRAV,ISTEP)                                  ADV0010
C         SUBROUTINE ADVECT  IS CALLED IF IADT .NE. 0.  THIS                 ADV0020
C          ROUTINE READS UNIT 21 FOR WIND SPEED AND DIRECTION TO             ADV0030
C          ADVECT THE PUFFS.                                                 ADV0040
      DIMENSION WSPD(100), WDIR(100), FRMAT(18)                              ADV0050
      COMMON /XP/ XPUFF(600),YPUFF(600),ZPUFF(600),ITPUFF(600),              ADV0060
     1XDSP(600),QPUFF(600),SY(600),SZ(600),CONC(25),NREC,KEYP(600)           ADV0070
      COMMON /ADVCT/ PDIR(600),PSPD(600),XSWC,YSWC,NUMX,NUMY,DX,DY,FRMAT     ADV0080
      NT = NUMX*NUMY                                                         ADV0090
      IF (ITRAV.EQ.ISTEP) READ (21,FRMAT) (WSPD(I),WDIR(I),I=1,NT)           ADV0100
C         READ UNIT 21 IF THE FIRST TIME STEP OF EACH MET. PERIOD.           ADV0110
C          WIND SPEED AND DIRECTION ARE READ IN FOR EACH GRID                ADV0120
C          SQUARE, A ROW AT A TIME, FROM WEST TO EAST (LEFT TO               ADV0130
C          RIGHT). ROWS ARE READ FROM SOUTH TO NORTH (BOTTOM TO              ADV0140
C          TOP).                                                             ADV0150
C         FRMAT IS THE FORMAT OF FILE 21 (MET. DATA).                        ADV0160
      DO 10 I=1,NPUFF                                                        ADV0170
1        X = XPUFF(I)/(1000.*DX) - XSWC + 1                                  ADV0180
1        Y = YPUFF(I)/(1000.*DY) - YSWC + 1                                  ADV0190
1        IX = X                                                              ADV0200
1        IY = Y                                                              ADV0210
1        IF (IX.GT.NUMX.OR.IY.GT.NUMY) GO TO 10                              ADV0220
1           IP = (IY-1)*NUMX + IX                                            ADV0230
1           PDIR(I) = WDIR(IP)                                               ADV0240
1           PSPD(I) = WSPD(IP)                                               ADV0250
1     10 CONTINUE                                                           ADV0260
      RETURN                                                                 ADV0270
      END                                                                    ADV0280
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      SUBROUTINE CONCEN (NPUFF,IST10,ITP)                                    CON0010
C         SUBROUTINE CONCEN COMPUTES THE CONCENTRATION AT                     CON0020
C          EACH RECEPTOR.                                                    CON0030
      COMMON /WEA/ WDIR(144),WSPD(144),HL(144),SGTH(144),SGPH(144),          CON0040
     1PREP(144),XYOP(600),XZOP(600),ITIME,KST(144),STANUM,SK(144),           CON0050
     2SV(144),UPLM(144)                                                      CON0060
      COMMON /XP/ XPUFF(600),YPUFF(600),ZPUFF(600),ITPUFF(600),              CON0070
     1XDSP(600),QPUFF(600),SY(600),SZ(600),CONC(25),NREC,KEYP(600)           CON0080
      COMMON /STA/ QP,HPP,TSP,VSP,DP,VFP,SYOP,SZOP,DH                        CON0090
      COMMON /REC/ XREC(25),YREC(25),ZREC(25),ALPHA,ANHGT                    CON0100
      PI = 3.141593                                                          CON0110
      PHI2 = 15.7496                                                         CON0120
C         RECEPTOR LOOP.                                                     CON0130
      DO 50 IREC=1,NREC                                                      CON0140
1     XR = XREC(IREC)*1000.                                                  CON0150
1     YR = YREC(IREC)*1000.                                                  CON0160
1     ZR = ZREC(IREC)                                                        CON0170
1     SUM = 0.                                                               CON0180
C           PUFF LOOP.                                                       CON0190
1     DO 40 IPUFF=1,NPUFF                                                    CON0200
2     Q = QPUFF(IPUFF)                                                       CON0210
2     R = SQRT((XPUFF(IPUFF)-XR)**2 + (YPUFF(IPUFF)-YR)**2)                  CON0220
2C         R IS THE DISTANCE OF PUFF FROM RECEPTOR XR,YR.                    CON0230
2     SRR = SY(IPUFF)                                                        CON0240
2     SZZ = SZ(IPUFF)                                                        CON0250
2     SR10 = STANUM*SRR                                                      CON0260
2     IF (R.GT.SR10) GO TO 30                                                CON0270
2C          CHECK THAT PUFF IS CLOSE ENOUGH TO RECEPTOR TO                   CON0280
2C           CONTRIBUTE TO CONCENTRATION                                     CON0290
2       C1 = Q/(SRR*SRR*SZZ*PHI2)                                            CON0300
2       C2 = -((R/SRR)**2)/2.                                                CON0310
2       EXC2 = 0.                                                            CON0320
2       IF (C2.GT.-50.) EXC2 = EXP(C2)                                       CON0330
2       IF (KEYP(IPUFF).EQ.4.OR.KEYP(IPUFF).EQ.6) GO TO 10                   CON0340
2         C3 = -.5*(((ZR-ZPUFF(IPUFF))/SZZ)**2)                              CON0350
2         EXC3 = 0.                                                          CON0360
2         IF (C3.GT.-50.) EXC3 = EXP(C3)                                     CON0370
2         C4 = -.5*(((ZR + ZPUFF(IPUFF))/SZZ)**2)                            CON0380
2         EXC4 = 0.                                                          CON0390
2         IF (C4.GT.-50.) EXC4 = EXP(C4)                                     CON0400
2         CON = C1*EXC2*(EXC3 + EXC4)                                        CON0410
2         GO TO 20                                                           CON0420
2       CONTINUE                                                             CON0430
2C       WELL-MIXED PUFF                                                     CON0440
2       CON = 2.*C1*EXC2                                                     CON0450
2       SUM = SUM + CON                                                      CON0460
2     CONTINUE                                                               CON0470
2     CONTINUE                                                               CON0480
1     CONC(IREC) = SUM                                                       CON0490
1   CONTINUE                                                                 CON0500
      IRM = MOD(ITP,IST10)                                                   CON0510
      IF (IRM.NE.0) GO TO 100                                                CON0520
        DO 70 I=2,NPUFF,2                                                    CON0530
C         PUFF COMBINATIONS                                                  CON0540
1       IF (KEYP(I).NE.KEYP(I-1)) GO TO 70                                   CON0550
1       RCOM = SQRT((XPUFF(I)-XPUFF(I-1))**2 +                               CON0560
1    1                (YPUFF(I)-YPUFF(I-1))**2)                             CON0570
1       TESIG = ALPHA*SY(I)                                                  CON0580
1       IF (RCOM-TESIG) 60,60,70                                             CON0590
1C          TEST FOR PUFF COMBINATION.                                       CON0600
1C          NOTE THAT POSITION, DISPLACEMENT AND TRAVEL TIME ARE             CON0610
1C           AVERAGED; MASS IS SUMMED; DISPERSION PARAMETERS,                CON0620
1C           VIRTUAL POSITION, AND PUFF KEY ARE THAT OF THE                  CON0630
1C           YOUNGER PUFF.                                                   CON0640
1   60    XPUFF(I-1) = (XPUFF(I-1) + XPUFF(I))/2.                            CON0650
1         YPUFF(I-1) = (YPUFF(I-1) + YPUFF(I))/2.                            CON0660
1         ZPUFF(I-1) = (ZPUFF(I-1) + ZPUFF(I))/2.                            CON0670
1         QPUFF(I-1) = QPUFF(I-1) + QPUFF(I)                                 CON0680
1         ITPUFF(I-1) = (ITPUFF(I-1) + ITPUFF(I))/2.                         CON0690
1         XDSP(I-1) = (XDSP(I-1) + XDSP(I))/2.                               CON0700
1         QPUFF(I) = -1.                                                     CON0710
1   70  CONTINUE                                                             CON0720
        N = 0                                                                CON0730
        DO 90 I=1,NPUFF                                                      CON0740
C         REMOVE TAGGED PUFFS AND COMPUTE NUMBER OF PUFFS                    CON0750
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                C              AFTER PUFF COMBINATION.                          CON0760
1               IF (QPUFF(I)) 90,80,80                                          CON0770
1     80        N             = N + 1                                           CON0780
1               XPUFF(N)      = XPUFF(I)                                        CON0790
1               YPUFF(N)      = YPUFF(I)                                        CON0800
1               ZPUFF(N)      = ZPUFF(I)                                        CON0810
1               QPUFF(N)      = QPUFF(I)                                        CON0820
1               ITPUFF(N)     = ITPUFF(I)                                       CON0830
1               SY(N)         = SY(I)                                           CON0840
1               SZ(N)         = SZ(I)                                           CON0850
1               XYOP(N)       = XYOP(I)                                         CON0860
1               XZOP(N)       = XZOP(I)                                         CON0870
1               KEYP(N)       = KEYP(I)                                         CON0880
1               XDSP(N)       = XDSP(I)                                         CON0890
1     90      CONTINUE                                                          CON0900
              NPUFF = N                                                         CON0910
    100     RETURN                                                              CON0920
            END                                                                 CON0930
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            SUBROUTINE JSISIG(KEY,IT,T,KS,SY,SZ)                               JSI0010
C               SUBROUTINE JSISIG COMPUTES SIGMAS BASED ON TRAVEL TIME          JSI0020
C               BASED ON IRWIN (1983) WHICH CULMINATES WORK BY DRAXLER          JSI0030
C                (1976) AND CRAMER (1976).                                      JSI0040
            COMMON /WEA/ WDIR(144),WSPD(144),HL(144),SGTH(144),SGPH(144),       JSI0050
           1PREP(144),XYOP(600),XZOP(600),ITIME,KST(144),STANUM,                JSI0060
           2SW(144),SV(144),UPLM(144)                                           JSI0070
            SIGV = SV(IT)                                                       JSI0080
            SIGW = SW(IT)                                                       JSI0090
            IF (KEY.EQ.3.OR.KEY.EQ.5) SIGW = 0.01                               JSI0100
            FY = 1.0 + 0.9*SQRT(T/1000.)                                        JSI0110
            SY = SIGV*T*(1./FY)                                                 JSI0120
            FZ = 1.                                                             JSI0130
            IF (KS.GT.4) FZ = 1.0 + 0.9*SQRT(T/50.)                             JSI0140
            SZ = SIGW*T*(1./FZ)                                                 JSI0150
            RETURN                                                              JSI0160
            END                                                                 JSI0170
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            SUBROUTINE LTSIG(SYY,DT,SY)                                         LTS0010
C               SUBROUTINE LTSIG COMPUTES THE SIGMAS FOR LONG RANGE             LTS0020
C                TRANSPORT, PROPORTIONAL TO THE SQRT(TIME).                     LTS0030
C               BASED ON DRAXLER (1976).                                        LTS0040
            TSTR = 9166.6667                                                    LTS0050
            A = 10.4446                                                         LTS0060
            DELT = ((SYY/A)**2 - TSTR) + DT                                     LTS0070
            SY = A*SQRT(TSTR + DELT)                                            LTS0080
            RETURN                                                              LTS0090
            END                                                                 LTS0100
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      786.          SUBROUTINE PGSIG (X,XY,KST,SY,SZ)                                  PGS0010
      787.    C         D. B. TURNER, ENVIRONMENTAL APPLICATIONS BRANCH                 PGS0020
      788.    C         METEOROLOGY LABORATORY, ENVIRONMENTAL PROTECTION AGENCY         PGS0030
      789.    C         RESEARCH TRIANGLE PARK, N C 27711                               PGS0040
      790.    C         (919) 549 - 8411, EXTENSION 4565                                PGS0050
      791.    C         VERTICAL DISPERSION PARAMETER VALUE, SZ DETERMINED BY           PGS0060
      792.    C          SZ = A * X ** B WHERE A AND B ARE FUNCTIONS OF BOTH STABILITY  PGS0070
      793.    C          AND RANGE OF X.                                                PGS0080
      794.    C         HORIZONTAL DISPERSION PARAMETER VALUE, SY DETERMINED BY          PGS0090
      795.    C          LOGARITHMIC INTERPOLATION OF PLUME HALF-ANGLE ACCORDING TO     PGS0100
      796.    C          DISTANCE AND CALCULATION OF 1/2.15 TIMES HALF-ARC LENGTH.      PGS0110
      797.          DIMENSION XA(7), XB(2), XD(5), XE(8), XF(9), AA(8), BA(8), AB(3),   PGS0120
      798.         1BB(3), AD(6), BD(6), AE(9), BE(9), AF(10), BF(10)                   PGS0130
      799.          DATA XA /.5,.4,.3,.25,.2,.15,.1/                                   PGS0140
      800.          DATA XB /.4,.2/                                                    PGS0150
      801.          DATA XD /30.,10.,3.,1.,.3/                                         PGS0160
      802.          DATA XE /40.,20.,10.,4.,2.,1.,.3,.1/                               PGS0170
      803.          DATA XF /60.,30.,15.,7.,3.,2.,1.,.7,.2/                            PGS0180
      804.          DATA AA /453.85,346.75,258.89,217.41,179.52,170.22,158.08,122.8/   PGS0190
      805.          DATA BA /2.1166,1.7283,1.4094,1.2644,1.1262,1.0932,1.0542,.9447/   PGS0200
      806.          DATA AB /109.30,98.483,90.673/                                     PGS0210
      807.          DATA BB /1.0971,0.98332,0.93198/                                   PGS0220
      808.          DATA AD /44.053,36.650,33.504,32.093,32.093,34.459/                PGS0230
      809.          DATA BD /0.51179,0.56589,0.60486,0.64403,0.81066,0.86974/          PGS0240
      810.          DATA AE /47.618,35.420,26.970,24.703,22.534,21.628,21.628,23.331,  PGS0250
      811.         124.26/                                                             PGS0260
      812.          DATA BE /0.29592,0.37615,0.46713,0.50527,0.57154,0.63077,0.75660,  PGS0270
      813.         10.81956,0.8366/                                                    PGS0280
      814.          DATA AF /34.219,27.074,22.651,17.836,16.187,14.823,13.953,13.953,  PGS0290
      815.         114.457,15.209/                                                     PGS0300
      816.          DATA BF /0.21716,0.27436,0.32681,0.41507,0.46490,0.54503,0.63227,  PGS0310
      817.         10.68465,0.78407,0.81558/                                           PGS0320
      818.          GO TO (10,40,70,75,80,110,140), KST                                PGS0330
      819.    C          STABILITY A (10)                                              PGS0340
      820.    10    TH = (24.167 - 2.5334*ALOG(XY))/57.2958                            PGS0350
      821.          IF (X.GT.3.11) GO TO 170                                           PGS0360
      822.          DO 20 ID=1,7                                                       PGS0370
1     823.             IF (X.GE.XA(ID)) GO TO 30                                       PGS0380
1     824.    20    CONTINUE                                                           PGS0390
      825.          ID = 8                                                             PGS0400
      826.    30    SZ = AA(ID)*X**BA(ID)                                              PGS0410
      827.          GO TO 190                                                          PGS0420
      828.    C          STABILITY B (40)                                              PGS0430
      829.    40    TH = (18.333 - 1.8096*ALOG(XY))/57.2958                            PGS0440
      830.          IF (X.GT.35.) GO TO 170                                            PGS0450
      831.          DO 50 ID=1,2                                                       PGS0460
1     832.             IF (X.GE.XB(ID)) GO TO 60                                       PGS0470
1     833.    50    CONTINUE                                                           PGS0480
      834.          ID = 3                                                             PGS0490
      835.    60    SZ = AB(ID)*X**BB(ID)                                              PGS0500
      836.          GO TO 180                                                          PGS0510
      837.    C          STABILITY C (70)                                              PGS0520
      838.    70    TH = (12.5 - 1.0857*ALOG(XY))/57.2958                              PGS0530
      839.          SZ = 61.141*X**0.91465                                             PGS0540
      840.          GO TO 180                                                          PGS0550
      841.    C          D DAY TIME                                                    PGS0560
      842.    75    TH = (8.3333 - 0.72382*ALOG(XY))/57.2958                           PGS0570
      843.          SZ = 30.9057*X**0.8273                                             PGS0580
      844.          GO TO 180                                                          PGS0590
      845.    C          STABILITY D (80)                                              PGS0600
      846.    80    TH = (8.3333 - 0.72382*ALOG(XY))/57.2958                           PGS0610
      847.          DO 90 ID=1,5                                                       PGS0620
1     848.             IF (X.GE.XD(ID)) GO TO 100                                      PGS0630
1     849.    90    CONTINUE                                                           PGS0640
      850.          ID = 6                                                             PGS0650
      851.   100    SZ = AD(ID)*X**BD(ID)                                              PGS0660
      852.          GO TO 180                                                          PGS0670
      853.    C          STABILITY E (110)                                             PGS0680
      854.   110    TH = (6.25 - 0.54287*ALOG(XY))/57.2958                             PGS0690
      855.          DO 120 ID=1,8                                                      PGS0700
1     856.             IF (X.GE.XE(ID)) GO TO 130                                      PGS0710
1     857.   120    CONTINUE                                                           PGS0720
      858.          ID = 9                                                             PGS0730
      859.   130    SZ = AE(ID)*X**BE(ID)                                              PGS0740
      860.          GO TO 180                                                          PGS0750
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      861.  C         STABILITY F (140)                                    PGS0760
      862.  140   TH = (4.1667 - 0.36191*ALOG(XY))/57.2958                 PGS0770
      863.        DO 150 ID=1,9                                            PGS0780
1     864.          IF (X.GE.XF(ID)) GO TO 160                             PGS0790
1     865.  150   CONTINUE                                                 PGS0800
      866.        ID = 10                                                  PGS0810
      867.  160   SZ = AF(ID)*X**BF(ID)                                    PGS0820
      868.        GO TO 180                                                PGS0830
      869.  170   SZ = 5000.                                               PGS0840
      870.        GO TO 190                                                PGS0850
      871.  180   IF (SZ.GT.5000.) SZ = 5000.                             PGS0860
      872.  190   SY = 465.116*XY*SIN(TH)/COS(TH)                         PGS0870
      873.  C         465.116 = 1000. (M/KM) / 2.15                        PGS0880
      874.        RETURN                                                   PGS0890
      875.        END                                                      PGS0900
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      SUBROUTINE PLMRS(KST,U,TEMP,PL,IOPT,HANE,DELH,H)                  PLR0010
      COMMON /STA/ QP,HPP,TSP,VSP,DP,VFP,SYOP,SZOP,DH                   PLR0020
      VS = VSP                                                          PLR0030
      TS = TSP                                                          PLR0040
      D = DP                                                            PLR0050
C         MODIFY WIND SPEED BY POWER LAW PROFILE IN ORDER TO TAKE INTO   PLR0060
C          ACCOUNT THE INCREASE OF WIND SPEED WITH HEIGHT.              PLR0070
C         ASSUME WIND MEASUREMENTS ARE REPRESENTATIVE FOR HEIGHT=HANE.   PLR0080
C         THT IS THE PHYSICAL STACK HEIGHT                              PLR0090
      THT = HPP                                                         PLR0100
C         POINT SOURCE HEIGHT NOT ALLOWED TO BE LESS THAN 1 METER.      PLR0110
      IF (THT.LT.1.) THT = 1.                                           PLR0120
C         U - WIND SPEED AT HEIGHT 'HANE'                               PLR0130
C         PL - POWER FOR THE WIND PROFILE                               PLR0140
C         UPL - WIND AT THE PHYSICAL STACK HEIGHT                       PLR0150
      UPL = U*(THT/HANE)**PL                                            PLR0160
C         WIND SPEED NOT ALLOWED TO BE LESS THAN 1 METER/SEC.           PLR0170
      IF (UPL.LT.1.) UPL = 1.                                           PLR0180
      BUOY = 2.45153*VS*D**2                                            PLR0190
C         TEMP- THE AMBIENT AIR TEMPERATURE FOR THIS HOUR               PLR0200
      DELT = TS - TEMP                                                  PLR0210
      F = BUOY*DELT/TS                                                  PLR0220
C         CALCULATE  H PRIME WHICH TAKES INTO ACCOUNT STACK DOWNWASH     PLR0230
C          BRIGGS(1973) PAGE 4                                          PLR0240
      HPRM = THT                                                        PLR0250
C         IF IOPT=0, THEN NO STACK DOWNWASH COMPUTATION                 PLR0260
      IF (IOPT.EQ.0) GO TO 40                                           PLR0270
      DUM = VS/UPL                                                      PLR0280
      IF (DUM.LT.1.5) HPRM = THT + 2.*D*(DUM-1.5)                       PLR0290
C         'HPRM' IS BRIGGS' H-PRIME                                     PLR0300
      IF (HPRM.LT.0.) HPRM = 0.                                         PLR0310
   40 CONTINUE                                                          PLR0320
C         CALCULATE PLUME RISE AND ADD H PRIME TO OBTAIN EFFECTIVE      PLR0330
C         STACK HEIGHT.                                                 PLR0340
C        PLUME RISE CALCULATION                                         PLR0350
      IF (KST.GT.5) GO TO 60                                            PLR0360
C        PLUME RISE FOR UNSTABLE CONDITIONS                             PLR0370
      IF (TS.LT.TEMP) GO TO 70                                          PLR0380
      IF (F.GE.55.) GO TO 50                                            PLR0390
C        DETERMINE DELTA-T FOR BUOYANCY-MOMENTUM CROSSOVER(F<55)        PLR0400
C          FOUND BY EQUATING BRIGGS(1969) EQ 5.2, P 59 WITH             PLR0410
C          COMBINATION OF BRIGGS(1971) EQUATIONS 6 AND 7, P 1031        PLR0420
C          FOR F<55.                                                    PLR0430
      DTMB = 0.0297*TS*VS**0.33333/D**0.66667                           PLR0440
      IF (DELT.LT.DTMB) GO TO 70                                        PLR0450
C         DISTANCE OF FINAL BUOYANT RISE(0.049 IS 14*3.5/1000)          PLR0460
C          BRIGGS(1971) EQUATION 7,F<55, AND DIST TO FINAL RISE IS      PLR0470
C          3.5 XSTAR DISTF IN KILOMETERS                                PLR0480
      DISTF = 0.049*F**0.625                                            PLR0490
C         COMBINATION OF BRIGGS(1971) EQUATIONS 6 AND 7, P 1031 FOR     PLR0500
C          F<55.                                                        PLR0510
      DELH = 21.425*F**0.75/UPL                                         PLR0520
      GO TO 90                                                          PLR0530
C         DETERMINE DELTA-T FOR BUOYANCY-MOMENTUM CROSSOVER(F>55)       PLR0540
C          FOUND BY EQUATING BRIGGS(1969) EQ 5.2, P 59 WITH             PLR0550
C          COMBINATION OF BRIGGS(1971) EQUATIONS 6 AND 7, P 1031        PLR0560
C          FOR F>55.                                                    PLR0570
   50 DTMB = 0.00575*TS*VS**0.66667/D**0.33333                          PLR0580
      IF (DELT.LT.DTMB) GO TO 70                                        PLR0590
C         DISTANCE OF FINAL BUOYANT RISE (0.119 IS 34*3.5/1000)         PLR0600
C          BRIGGS(1971) EQUATION 7, F>55, AND DIST TO FINAL RISE        PLR0610
C          IS 3.5 XSTAR. DISTF IN KILOMETERS                            PLR0620
      DISTF = 0.119*F**0.4                                              PLR0630
C         COMBINATION OF BRIGGS(1971) EQUATIONS 6 AND 7, P 1031         PLR0640
C         FOR F>55.                                                     PLR0650
      DELH = 38.71*F**0.6/UPL                                           PLR0660
      GO TO 90                                                          PLR0670
C         PLUME RISE FOR STABLE CONDITIONS.                             PLR0680
   60 DTHDZ = 0.02                                                      PLR0690
      IF (KST.GT.5) DTHDZ = 0.035                                       PLR0700
      S = 9.80616*DTHDZ/TEMP                                            PLR0710
      IF (TS.LT.TEMP) GO TO 80                                          PLR0720
C         DETERMINE DELTA-T FOR BUOYANCY-MOMENTUM CROSSOVER(STABLE)     PLR0730
C          FOUND BY EQUATING BRIGGS(1975) EQ 59, PAGE 96 FOR STABLE     PLR0740
C          BUOYANCY RISE WITH BRIGGS(1969) EQ 4.28, PAGE 59 FOR         PLR0750
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951.   C          STABLE MOMENTUM RISE.                                          PLR0760
952.          DTMB = 0.019582*TEMP*VS*SQRT(S)                                    PLR0770
953.          IF (DELT.LT.DTMB) GO TO 80                                         PLR0780
954.   C          STABLE BUOYANT RISE FOR WIND CONDITIONS.(WIND NOT ALLOWED)      PLR0790
955.   C           LOW ENOUGH TO REQUIRE STABLE RISE IN CALM CONDITIONS.)         PLR0800
956.   C           BRIGGS(1975) EQ 59, PAGE 96.                                  PLR0810
957.          DELH = 2.6*(F/(UPL*S))**0.333333                                   PLR0820
958.   C          COMBINATION OF BRIGGS(1975) EQ 48 AND EQ 59. NOTE DISTF        PLR0830
959.   C           IN KM.                                                        PLR0840
960.          DISTF = 0.0020715*UPL/SQRT(S)                                      PLR0850
961.          GO TO 90                                                           PLR0860
962.   C          UNSTABLE-NEUTRAL MOMENTUM RISE                                PLR0870
963.   C           BRIGGS(1969) EQUATION 5.2, PAGE 59 NOTE: MOST ACCURATE        PLR0880
964.   C           WHEN VS/U>4; TENDS TO OVERESTIMATE RISE WHEN VS/U<4            PLR0890
965.   C           (SEE BRIGGS(1975) P 78, FIG 4.)                               PLR0900
966.   70     DELH = 3.*VS*D/UPL                                                 PLR0910
967.          DISTF = 0.                                                         PLR0920
968.          GO TO 90                                                           PLR0930
969.   C          STABLE MOMENTUM RISE                                          PLR0940
970.   80     DHA = 3.*VS*D/UPL                                                  PLR0950
971.   C          BRIGGS(1969) EQUATION 4.28, PAGE 59                           PLR0960
972.          DELH = 1.5*(VS*VS*D*D*TEMP/(4.*TS*UPL))**0.333333/S**0.166667      PLR0970
973.          IF (DHA.LT.DELH) DELH = DHA                                        PLR0980
974.   90     H = HPRM + DELH                                                    PLR0990
975.          RETURN                                                             PLR1000
976.          END                                                                PLR1010
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      977.          SUBROUTINE PROCES (NPUFF,ISTEP,DISKEY,IT,ITRAV,SYMAX,IADT)          PRO0010
      978.    C         SUBROUTINE PROCES ASSIGNS KEYP VALUES TO EACH PUFF AND          PRO0020
      979.    C          DETERMINES SIGMA VALUES FOR EACH PUFF.                         PRO0030
      980.          INTEGER DISKEY                                                      PRO0040
      981.          DIMENSION FRMAT(18)                                                 PRO0050
      982.          COMMON /WEA/ WDIR(144),WSPD(144),HL(144),SGTH(144),SGPH(144),       PRO0060
      983.         1PREP(144),XYOP(600),XZOP(600),ITIME,KST(144),STANUM,SW(144),        PRO0070
      984.         2SV(144),UPLM(144)                                                   PRO0080
      985.          COMMON /XP/ XPUFF(600),YPUFF(600),ZPUFF(600),ITPUFF(600),           PRO0090
      986.         1XDSP(600),QPUFF(600),SY(600),SZ(600),CONC(25),NREC,KEYP(600)        PRO0100
      987.          COMMON /ADVCT/ PDIR(600),PSPD(600),XSWC,YSWC,NUMX,NUMY,DX,DY,FRMAT  PRO0110
      988.          DT = ISTEP                                                          PRO0120
      989.          HL8 = 0.8*HL(IT)                                                    PRO0130
      990.          IHL = HL(IT)                                                        PRO0140
      991.          IF (IHLT.EQ.IHL) GO TO 20                                           PRO0150
      992.    C         IF CURRENT MIXED LAYER IS DIFFERENT THAN PREVIOUS              PRO0160
      993.    C          ONE, UPDATE KEYP(J)'S.                                        PRO0170
      994.             DO 10 I=1,NPUFF                                                  PRO0180
    1 995.                IF (KEYP(I).EQ.4.OR.KEYP(I).EQ.6) GO TO 10                    PRO0190
    1 996.                IF (KEYP(I).EQ.3.AND.ZPUFF(I).LT.IHL) KEYP(I) = 1             PRO0200
    1 997.                IF (KEYP(I).EQ.5.AND.ZPUFF(I).LT.IHL) KEYP(I) = 2             PRO0210
    1 998.                IF (KST(IT).GE.5) GO TO 10                                    PRO0220
    1 999.                IF (KEYP(I).EQ.3.OR.KEYP(I).EQ.5) GO TO 10                    PRO0230
    1 1000.               IF (SZ(I).GE.HL8) KEYP(I) = 4                                 PRO0240
    1 1001.   10        CONTINUE                                                        PRO0250
      1002.             IHLT = IHL                                                      PRO0260
      1003.   20    CONTINUE                                                          PRO0270
      1004.         GO TO (30,130), DISKEY                                            PRO0280
      1005.   C         DISKEY=1 FOR PG CURVES.                                       PRO0290
      1006.   C         DISKEY=2 FOR TRAVEL TIME CURVES                               PRO0300
      1007.   30    CONTINUE                                                          PRO0310
      1008.         IF (IT.EQ.1) GO TO 50                                             PRO0320
      1009.         IF (ITRAV.NE.ISTEP) GO TO 50                                      PRO0330
      1010.   C         AT THE FIRST TIME STEP OF EACH NEW MET. PERIOD FIND THE        PRO0340
      1011.   C          VIRTUAL DISTANCES FOR EACH PUFF.                             PRO0350
      1012.             DO 40 I=1,NPUFF                                               PRO0360
    1 1013.               XDSP(I) = 0.                                                PRO0370
    1 1014.   C            SET TRAVEL DISTANCE=0. AT THE BEGINNING OF NEW             PRO0380
    1 1015.   C             MET. PERIOD.                                              PRO0390
    1 1016.               IF (KEYP(I).EQ.6) GO TO 40                                  PRO0400
    1 1017.   C            NO VIRTUAL DISTANCE COMPUTATION IS NECESSARY IF KEYP=6      PRO0410
    1 1018.               KS = KST(IT)                                                PRO0420
    1 1019.               IF (KEYP(I).EQ.3.OR.KEYP(I).EQ.5) KS = 7                    PRO0430
    1 1020.               XYOP(I) = XVY(SY(I),KS)                                     PRO0440
    1 1021.               XZOP(I) = XVZ(SZ(I),KS)                                     PRO0450
    1 1022.   C            XYOP AND XZOP ARE VIRTUAL DISTANCES FOR EACH PUFF.        PRO0460
    1 1023.   40        CONTINUE                                                      PRO0470
      1024.   50    CONTINUE                                                          PRO0480
      1025.         X = DT*UPLM(IT)/1000.                                             PRO0490
      1026.   C         BEGIN LOOP OVER PUFFS FOR PG CURVES                           PRO0500
      1027.         DO 120 J=1,NPUFF                                                  PRO0510
    1 1028.         IF (IADT.NE.0) X = DT*PSPD(J)/1000.                               PRO0520
    1 1029.         TI = ITPUFF(NPUFF) - ITPUFF(J)                                    PRO0530
    1 1030.   C         AGE OF PUFF(J) IS COMPUTED BY SUBTRACTING THE TIME OF         PRO0540
    1 1031.   C          RELEASE OF PUFF(J) FROM THE TIME OF RELEASE OF THE MOST      PRO0550
    1 1032.   C          CURRENT PUFF.                                                PRO0560
    1 1033.         IF (TI.LT.0.5) GO TO 120                                          PRO0570
    1 1034.         KS = KST(IT)                                                      PRO0580
    1 1035.         GO TO (60,70,80,90,100,110), KEYP(J)                              PRO0590
    1 1036.   C         KEYP(J)=1 PUFF BELOW MIXED LAYER AND SHORT RANGE              PRO0600
    1 1037.   C         KEYP(J)=2 USE SIGMAS APPROPRIATE FOR LONG TRAVEL TIMES.       PRO0610
    1 1038.   C         KEYP(J)=3 PUFF ABOVE MIXED LAYER                              PRO0620
    1 1039.   C         KEYP(J)=4 PUFF WELL MIXED AND SHORT RANGE                     PRO0630
    1 1040.   C         KEYP(J)=5 PUFF ABOVE MIXED LAYER AND LONG RANGE               PRO0640
    1 1041.   C         KEYP(J)=6 LONG TRAVEL TIME AND WELL MIXED.                    PRO0650
    1 1042.   60    CONTINUE                                                          PRO0660
    1 1043.   C         KEYP=1                                                        PRO0670
    1 1044.         XDSP(J) = XDSP(J) + X                                             PRO0680
    1 1045.         XVYL = XDSP(J) + XYOP(J)                                          PRO0690
    1 1046.         XVZL = XDSP(J) + XZOP(J)                                          PRO0700
    1 1047.         CALL PGSIG (XVZL,XVYL,KS,SYD,SZD)                                 PRO0710
    1 1048.         SY(J) = SYD                                                       PRO0720
    1 1049.         SZ(J) = SZD                                                       PRO0730
    1 1050.         IF (SY(J).GE.SYMAX) KEYP(J) = 2                                   PRO0740
    1 1051.         IF (SY(J).GE.SYMAX) SY(J) = SYMAX                                 PRO0750
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1     1052.          IF (KS.GE.5) GO TO 120                                                    PRO0760
1     1053.          IF (SZ(J).GE.HL8) KEYP(J) = 4                                             PRO0770
1     1054.          IF (SZ(J).GE.HL8) SZ(J) = HL8                                             PRO0780
1     1055.          IF (SY(J).GE.SYMAX.AND.KEYP(J).EQ.4) KEYP(J) = 6                          PRO0790
1     1056.          GO TO 120                                                                 PRO0800
1     1057.    70    CONTINUE                                                                  PRO0810
1     1058.    C         KEYP=2                                                                PRO0820
1     1059.          XDSP(J) = XDSP(J) + X                                                     PRO0830
1     1060.          XVZL = XDSP(J) + XZOP(J)                                                  PRO0840
1     1061.          SYY = SY(J)                                                               PRO0850
1     1062.          CALL LTSIG (SYY,DT,SYD)                                                   PRO0860
1     1063.          SY(J) = SYD                                                               PRO0870
1     1064.          CALL PGSIG (XVZL,XVYL,KS,SYD,SZD)                                         PRO0880
1     1065.          SZ(J) = SZD                                                               PRO0890
1     1066.          IF (KS.GE.5) GO TO 120                                                    PRO0900
1     1067.          IF (SZ(J).GE.HL8) KEYP(J) = 6                                             PRO0910
1     1068.          IF (SZ(J).GE.HL8) SZ(J) = HL8                                             PRO0920
1     1069.          GO TO 120                                                                 PRO0930
1     1070.    80    CONTINUE                                                                  PRO0940
1     1071.    C         KEYP=3                                                                PRO0950
1     1072.          XDSP(J) = XDSP(J) + X                                                     PRO0960
1     1073.          XVYL = XDSP(J) + XYOP(J)                                                  PRO0970
1     1074.          XVZL = XDSP(J) + XZOP(J)                                                  PRO0980
1     1075.          CALL PGSIG (XVZL,XVYL,7,SYD,SZD)                                          PRO0990
1     1076.          SY(J) = SYD                                                               PRO1000
1     1077.          SZ(J) = SZD                                                               PRO1010
1     1078.          IF (SY(J).GE.SYMAX) KEYP(J) = 5                                           PRO1020
1     1079.          IF (SY(J).GE.SYMAX) SY(J) = SYMAX                                         PRO1030
1     1080.          GO TO 120                                                                 PRO1040
1     1081.    90    CONTINUE                                                                  PRO1050
1     1082.    C         KEYP=4                                                                PRO1060
1     1083.          XDSP(J) = XDSP(J) + X                                                     PRO1070
1     1084.          XVYL = XDSP(J) + XYOP(J)                                                  PRO1080
1     1085.          CALL PGSIG (XVZL,XVYL,KS,SYD,SZD)                                         PRO1090
1     1086.          SY(J) = SYD                                                               PRO1100
1     1087.          IF (SZ(J).LT.HL8) SZ(J) = HL8                                             PRO1110
1     1088.          IF (SY(J).GE.SYMAX) KEYP(J) = 6                                           PRO1120
1     1089.          IF (SY(J).GE.SYMAX) SY(J) = SYMAX                                         PRO1130
1     1090.          GO TO 120                                                                 PRO1140
1     1091.    100   CONTINUE                                                                  PRO1150
1     1092.    C         KEYP=5                                                                PRO1160
1     1093.          XDSP(J) = XDSP(J) + X                                                     PRO1170
1     1094.          XVZL = XDSP(J) + XZOP(J)                                                  PRO1180
1     1095.          CALL PGSIG (XVZL,XVYL,7,SYD,SZD)                                          PRO1190
1     1096.          SZ(J) = SZD                                                               PRO1200
1     1097.          SYY = SY(J)                                                               PRO1210
1     1098.          CALL LTSIG (SYY,DT,SYD)                                                   PRO1220
1     1099.          SY(J) = SYD                                                               PRO1230
1     1100.          GO TO 120                                                                 PRO1240
1     1101.    110   CONTINUE                                                                  PRO1250
1     1102.    C         KEYP=6                                                                PRO1260
1     1103.          XDSP(J) = XDSP(J) + X                                                     PRO1270
1     1104.          SYY = SY(J)                                                               PRO1280
1     1105.          CALL LTSIG (SYY,DT,SYD)                                                   PRO1290
1     1106.          SY(J) = SYD                                                               PRO1300
1     1107.          IF (SZ(J).LT.HL8) SZ(J) = HL8                                             PRO1310
1     1108.    120   CONTINUE                                                                  PRO1320
1     1109.    C         END LOOP OVER PUFFS FOR PG CURVES                                     PRO1330
      1110.          GO TO 230                                                                 PRO1340
      1111.    130   CONTINUE                                                                  PRO1350
      1112.    C         DISPERSION AS A FUNCTION OF TIME.                                     PRO1360
      1113.          IF (IT.EQ.1) GO TO 150                                                    PRO1370
      1114.          IF (ITRAV.NE.ISTEP) GO TO 150                                             PRO1380
      1115.             DO 140 I=1,NPUFF                                                       PRO1390
1     1116.                XDSP(I) = 0.                                                        PRO1400
1     1117.                IF (KEYP(I).EQ.6) GO TO 140                                         PRO1410
1     1118.                KS = KST(IT)                                                        PRO1420
1     1119.                IF (KEYP(I).EQ.3.OR.KEYP(I).EQ.5) KS = 7                            PRO1430
1     1120.                CALL VTIME (KEYP(I),IT,KS,SY(I),SZ(I),XYOP(I),XZOP(I))              PRO1440
1     1121.    140       CONTINUE                                                              PRO1450
      1122.    150   CONTINUE                                                                  PRO1460
      1123.    C         BEGIN LOOP OVER PUFFS FOR TRAVEL TIME CURVES                          PRO1470
      1124.          DO 220 J=1,NPUFF                                                          PRO1480
1     1125.          KS = KST(IT)                                                              PRO1490
1     1126.          TI = ITPUFF(NPUFF) - ITPUFF(J)                                            PRO1500
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1     1127.          IF (TI.LT.0.5) GO TO 220                                    PRO1510
1     1128.          GO TO (160,170,180,190,200,210), KEYP(J)                    PRO1520
1     1129.    160   CONTINUE                                                    PRO1530
1     1130.    C         KEYP=1                                                  PRO1540
1     1131.          XDSP(J) = XDSP(J) + ISTEP                                   PRO1550
1     1132.          TVY = XDSP(J) + XYOP(J)                                     PRO1560
1     1133.          TVZ = XDSP(J) + XZOP(J)                                     PRO1570
1     1134.          CALL JSISIG (KEYP(J),IT,TVY,KS,SYD,SZD)                     PRO1580
1     1135.          SY(J) = SYD                                                 PRO1590
1     1136.          IF (SY(J).GE.SYMAX) KEYP(J) = 2                             PRO1600
1     1137.          IF (SY(J).GE.SYMAX) SY(J) = SYMAX                           PRO1610
1     1138.          CALL JSISIG (KEYP(J),IT,TVZ,KS,SYD,SZD)                     PRO1620
1     1139.          SZ(J) = SZD                                                 PRO1630
1     1140.          IF (KS.GE.5) GO TO 220                                      PRO1640
1     1141.          IF (SZ(J).GE.HL8) KEYP(J) = 4                               PRO1650
1     1142.          IF (SZ(J).GE.HL8) SZ(J) = HL8                               PRO1660
1     1143.          IF (SY(J).GE.SYMAX.AND.KEYP(J).EQ.4) KEYP(J) = 6            PRO1670
1     1144.          GO TO 220                                                   PRO1680
1     1145.    170   CONTINUE                                                    PRO1690
1     1146.    C         KEYP=2                                                  PRO1700
1     1147.          XDSP(J) = XDSP(J) + ISTEP                                   PRO1710
1     1148.          SYY = SY(J)                                                 PRO1720
1     1149.          SZZ = SZ(J)                                                 PRO1730
1     1150.          CALL LTSIG (SYY,DT,SYD)                                     PRO1740
1     1151.          SY(J) = SYD                                                 PRO1750
1     1152.          TVZ = XDSP(J) + XZOP(J)                                     PRO1760
1     1153.          CALL JSISIG (KEYP(J),IT,TVZ,KS,SYD,SZD)                     PRO1770
1     1154.          SZ(J) = SZD                                                 PRO1780
1     1155.          IF (KS.GE.5) GO TO 220                                      PRO1790
1     1156.          IF (SZ(J).GE.HL8) KEYP(J) = 6                               PRO1800
1     1157.          IF (SZ(J).GE.HL8) SZ(J) = HL8                               PRO1810
1     1158.          GO TO 220                                                   PRO1820
1     1159.    180   CONTINUE                                                    PRO1830
1     1160.    C         KEYP=3                                                  PRO1840
1     1161.          KS = 7                                                      PRO1850
1     1162.          XDSP(J) = XDSP(J) + ISTEP                                   PRO1860
1     1163.          TVY = XDSP(J) + XYOP(J)                                     PRO1870
1     1164.          TVZ = XDSP(J) + XZOP(J)                                     PRO1880
1     1165.          CALL JSISIG (KEYP(J),IT,TVY,KS,SYD,SZD)                     PRO1890
1     1166.          SY(J) = SYD                                                 PRO1900
1     1167.          IF (SY(J).GE.SYMAX) KEYP(J) = 5                             PRO1910
1     1168.          IF (SY(J).GE.SYMAX) SY(J) = SYMAX                           PRO1920
1     1169.          CALL JSISIG (KEYP(J),IT,TVZ,KS,SYD,SZD)                     PRO1930
1     1170.          SZ(J) = SZD                                                 PRO1940
1     1171.          GO TO 220                                                   PRO1950
1     1172.    190   CONTINUE                                                    PRO1960
1     1173.    C         KEYP=4                                                  PRO1970
1     1174.          XDSP(J) = XDSP(J) + ISTEP                                   PRO1980
1     1175.          TVY = XDSP(J) + XYOP(J)                                     PRO1990
1     1176.          CALL JSISIG (KEYP(J),IT,TVY,KS,SYD,SZD)                     PRO2000
1     1177.          SY(J) = SYD                                                 PRO2010
1     1178.          IF (SY(J).GE.SYMAX) KEYP(J) = 6                             PRO2020
1     1179.          IF (SY(J).GE.SYMAX) SY(J) = SYMAX                           PRO2030
1     1180.          IF (SZ(J).LT.HL8) SZ(J) = HL8                               PRO2040
1     1181.          GO TO 220                                                   PRO2050
1     1182.    200   CONTINUE                                                    PRO2060
1     1183.    C         KEYP=5                                                  PRO2070
1     1184.          KS = 7                                                      PRO2080
1     1185.          XDSP(J) = XDSP(J) + ISTEP                                   PRO2090
1     1186.          SYY = SY(J)                                                 PRO2100
1     1187.          TVZ = XDSP(J) + XZOP(J)                                     PRO2110
1     1188.          CALL LTSIG (SYY,DT,SYD)                                     PRO2120
1     1189.          SY(J) = SYD                                                 PRO2130
1     1190.          CALL JSISIG (KEYP(J),IT,TVZ,KS,SYD,SZD)                     PRO2140
1     1191.          SZ(J) = SZD                                                 PRO2150
1     1192.          GO TO 220                                                   PRO2160
1     1193.    210   CONTINUE                                                    PRO2170
1     1194.    C         KEYP=6                                                  PRO2180
1     1195.          XDSP(J) = XDSP(J) + ISTEP                                   PRO2190
1     1196.          SYY = SY(J)                                                 PRO2200
1     1197.          CALL LTSIG (SYY,DT,SYD)                                     PRO2210
1     1198.          SY(J) = SYD                                                 PRO2220
1     1199.          IF (SZ(J).LT.HL8) SZ(J) = HL8                               PRO2230
1     1200.    220   CONTINUE                                                    PRO2240
1     1201.    C         END LOOP OVER PUFFS FOR TRAVEL TIME CURVES              PRO2250
      1202.    230   CONTINUE                                                    PRO2260
      1203.          RETURN                                                      PRO2270
      1204.          END                                                         PRO2280
```

```
      1205.          SUBROUTINE VTIME(KEY,IT,KS,SYO,SZO,XYO,XZO)                    VTI0010
      1206.    C         SUBROUTINE VTIME COMPUTES VIRTUAL TIMES. THIS PROCESS IS   VTI0020
      1207.    C          ANALOGOUS TO COMPUTING THE VIRTUAL DISTANCE.              VTI0030
      1208.          DO 200 IC=1,2                                                  VTI0040
    1 1209.             XINC = 0.                                                   VTI0050
    1 1210.             KD = 10                                                     VTI0060
    1 1211.             DO 150 K=1,KD                                               VTI0070
    2 1212.                DX = 10.**(KD-K)                                         VTI0080
    2 1213.                DO 140 J=1,10                                            VTI0090
    3 1214.                   XINC = XINC + DX                                      VTI0100
    3 1215.                   XINCR = XINC/1000.                                    VTI0110
    3 1216.                   CALL JSISIG(KEY,IT,XINCR,KS,SYD,SZD)                  VTI0120
    3 1217.                   DIFF = SYD - SYO                                      VTI0130
    3 1218.                   IF (IC.EQ.2) DIFF = SZD - SZO                         VTI0140
    3 1219.                   IF (DIFF) 140,155,145                                 VTI0150
    3 1220.   140           CONTINUE                                                VTI0160
    2 1221.   145           XINC = XINC - DX                                        VTI0170
    2 1222.   150        CONTINUE                                                   VTI0180
    1 1223.   155        CONTINUE                                                   VTI0190
    1 1224.            IF (IC.EQ.1) XYO = XINCR                                   VTI0200
    1 1225.            IF (IC.EQ.2) XZO = XINCR                                   VTI0210
    1 1226.   200    CONTINUE                                                       VTI0220
      1227.          RETURN                                                         VTI0230
      1228.          END                                                            VTI0240
```

```
      1229.          FUNCTION XVY (SYO,KST)                                         XVY0010
      1230.    C         XVY CALCULATES THE VIRTUAL DISTANCE NECESSARY TO           XVY0020
      1231.    C          ACCOUNT FOR THE INITIAL CROSSWIND DISPERTION.             XVY0030
      1232.          GO TO (10,20,30,40,50,60,70), KST                              XVY0040
      1233.    10    XVY = (SYO/213.)**1.1148                                       XVY0050
      1234.          RETURN                                                         XVY0060
      1235.    20    XVY = (SYO/155.)**1.097                                        XVY0070
      1236.          RETURN                                                         XVY0080
      1237.    30    XVY = (SYO/103.)**1.092                                        XVY0090
      1238.          RETURN                                                         XVY0100
      1239.    40    XVY = (SYO/68.)**1.076                                         XVY0110
      1240.          RETURN                                                         XVY0120
      1241.    C         D(DAY) AND D(NIGHT) ARE THE SAME FOR SIGMA Y.              XVY0130
      1242.    50    XVY = (SYO/68.)**1.076                                         XVY0140
      1243.          RETURN                                                         XVY0150
      1244.    60    XVY = (SYO/50.)**1.086                                         XVY0160
      1245.          RETURN                                                         XVY0170
      1246.    70    XVY = (SYO/33.5)**1.083                                        XVY0180
      1247.          RETURN                                                         XVY0190
      1248.          END                                                            XVY0200
```

```
      1249.          FUNCTION XVZ (SZO,KST)
      1250.    C
      1251.    C          XVZ CALCULATES THE VIRTUAL DISTANCE NECESSARY                    XVZ0010
      1252.    C           TO ACCOUNT FOR THE INITIAL VERTICAL DISPERTION.                 XVZ0020
      1253.          DIMENSION SA(7), SB(2), SD(5), SE(8), SF(9), AA(8), AB(3), AD(6),    XVZ0030
     1AE(9), AF(10), CA(8), CB(3), CD(6), CE(9), CF(10)                                   XVZ0040
      1254.          DATA SA /13.95,21.40,29.3,37.67,47.44,71.16,104.65/                  XVZ0050
      1255.          DATA SB /20.23,40./                                                  XVZ0060
      1256.          DATA SD /12.09,32.09,65.12,134.9,251.2/                              XVZ0070
      1257.          DATA SE /3.534,8.698,21.628,33.489,49.767,79.07,109.3,141.86/        XVZ0080
      1258.          DATA SF /4.093,10.93,13.953,21.627,26.976,40.,54.89,68.84,83.25/     XVZ0090
      1259.          DATA AA /122.8,158.08,170.22,179.52,217.41,258.89,346.75,453.85/     XVZ0100
      1260.          DATA AB /90.673,98.483,109.3/                                        XVZ0110
      1261.          DATA AD /34.459,32.093,32.093,33.304,36.650,44.053/                  XVZ0120
      1262.          DATA AE /24.26,23.331,21.628,21.628,22.534,24.703,26.97,35.42,       XVZ0130
      1263.         147.618/                                                              XVZ0140
      1264.          DATA AF /15.209,14.457,13.953,13.953,14.823,16.187,17.836,22.651,    XVZ0150
      1265.         127.074,34.219/                                                       XVZ0160
      1266.          DATA CA /1.0585,.9486,.9147,.8879,.7909,.7095,.5786,.4725/           XVZ0170
      1267.          DATA CB /1.073,1.317,.9115/                                          XVZ0180
      1268.          DATA CD /1.1498,1.2336,1.5527,1.6533,1.7671,1.9539/                  XVZ0190
      1269.          DATA CE /1.1953,1.2202,1.3217,1.5854,1.7497,1.9791,2.1407,2.6585,    XVZ0200
      1270.         13.3793/                                                              XVZ0210
      1271.          DATA CF /1.2261,1.2754,1.4606,1.5816,1.8348,2.151,2.4092,3.0599,     XVZ0220
      1272.         13.6448,4.6049/                                                       XVZ0230
      1273.          GO TO (10,40,70,75,80,110,140), KST                                  XVZ0240
      1274.    C          STABILITY A(10)                                                 XVZ0250
      1275.         10  DO 20 ID=1,7                                                      XVZ0260
     1 1276.             IF (SZO.LE.SA(ID)) GO TO 30                                     XVZ0270
     1 1277.         20  CONTINUE                                                        XVZ0280
      1278.              ID = 8                                                          XVZ0290
      1279.         30   XVZ = (SZO/AA(ID))**CA(ID)                                      XVZ0300
      1280.              RETURN                                                          XVZ0310
      1281.    C          STABILITY B (40)                                                XVZ0320
      1282.         40   DO 50 ID=1,2                                                    XVZ0330
     1 1283.             IF (SZO.LE.SB(ID)) GO TO 60                                     XVZ0340
     1 1284.         50  CONTINUE                                                        XVZ0350
      1285.              ID = 3                                                          XVZ0360
      1286.         60   XVZ = (SZO/AB(ID))**CB(ID)                                      XVZ0370
      1287.              RETURN                                                          XVZ0380
      1288.    C          STABILITY C (70)                                                XVZ0390
      1289.         70   XVZ = (SZO/61.141)**1.0933                                      XVZ0400
      1290.              RETURN                                                          XVZ0410
      1291.    C          STABILITY D(DAY)                                                XVZ0420
      1292.         75   XVZ = (SZO/30.9057)**1.2088                                     XVZ0430
      1293.              RETURN                                                          XVZ0440
      1294.    C          STABILITY D (80)                                                XVZ0450
      1295.         80   DO 90 ID=1,5                                                    XVZ0460
     1 1296.             IF (SZO.LE.SD(ID)) GO TO 100                                    XVZ0470
     1 1297.         90  CONTINUE                                                        XVZ0480
      1298.              ID = 6                                                          XVZ0490
      1299.         100  XVZ = (SZO/AD(ID))**CD(ID)                                      XVZ0500
      1300.              RETURN                                                          XVZ0510
      1301.    C          STABILITY E (110)                                               XVZ0520
      1302.         110  DO 120 ID=1,8                                                   XVZ0530
     1 1303.             IF (SZO.LE.SE(ID)) GO TO 130                                    XVZ0540
     1 1304.         120 CONTINUE                                                        XVZ0550
      1305.              ID = 9                                                          XVZ0560
      1306.         130  XVZ = (SZO/AE(ID))**CE(ID)                                      XVZ0570
      1307.              RETURN                                                          XVZ0580
      1308.    C          STABILITY F(140)                                                XVZ0590
      1309.         140  DO 150 ID=1,9                                                   XVZ0600
     1 1310.             IF (SZO.LE.SF(ID)) GO TO 160                                    XVZ0610
     1 1311.         150 CONTINUE                                                        XVZ0620
      1312.              ID = 10                                                         XVZ0630
      1313.         160  XVZ = (SZO/AF(ID))**CF(ID)                                      XVZ0640
      1314.              RETURN                                                          XVZ0650
      1315.              END                                                             XVZ0660
                                                                                          XVZ0670
```

PLOT POSTPROCESSOR

The source code listing of the plotting routine is presented in subsequent pages. The program consists of a main module and two subroutines.

```
      1.          COMMON /PUFTRJ/ XPAGE,YPAGE,XPUF(600),YPUF(600),SRR(600),XMIN,XMAX PLT0010
      2.         1,YMIN,YMAX,AXL,AYL,XREC(25),YREC(25),NREC                          PLT0020
      3.          COMMON /PUFCON/ XPG,YPG,XSI,YSI,CONT(3600),TIME(3600),TIMIN        PLT0030
      4.          DIMENSION CONC(25), IREC(25)                                       PLT0040
      5.          XSI=0.                                                             PLT0050
      6.          READ (5,*) IPLT                                                    PLT0060
      7.    C                   IF IPLT = 1 PLOT CONCENTRATION VS. TIME              PLT0070
      8.    C                   IF IPLT = 2 PLOT PUFF TRAJECTORY                     PLT0080
      9.    C                   IF IPLT = 3 PLOT BOTH                                PLT0090
     10.          IF (IPLT.EQ.1.OR.IPLT.EQ.3) READ (5,*) IYR,NUMR,ITPT,XSI,YSI       PLT0100
     11.    C                                                                        PLT0110
     12.    C       IYR IS THE ORDERS OF MAGNITUDE TO BE PLOTTED ON THE              PLT0120
     13.    C         Y AXIS. IF IYR = 0 THE DEFAULT VALUE WILL BE SET AT            PLT0130
     14.    C         IYR = 6.                                                       PLT0140
     15.    C       NUMR IS THE NUMBER OF RECEPTORS THAT                             PLT0150
     16.    C           CONCENTRATION VS. TIME IS PLOTTED FOR.                       PLT0160
     17.    C       ITPT IS THE NUMBER OF PERIODS YOU WANT PLOTTED TOGETHER.         PLT0170
     18.    C         ITPT MUST BE EVENLY DIVISABLE INTO NTIME. IF ITPT > 999        PLT0180
     19.    C         ALL PERIODS ARE PLOTTED TOGETHER.                              PLT0190
     20.    C       XSI LENGTH OF X AXIS IN INCHES                                   PLT0200
     21.    C       YSI LENGTH OF Y AXIS IN INCHES                                   PLT0210
     22.          IF (IPLT.EQ.1.OR.IPLT.EQ.3) READ (5,*) (IREC(I),I=1,NUMR)          PLT0220
     23.          IF (IPLT.EQ.2.OR.IPLT.EQ.3) READ (5,*) XMIN,YMIN,XSIZE,YSIZE,AXL,A PLT0230
     24.         1YL                                                                 PLT0240
     25.    C       XMIN        EAST-WEST COORDINATE OF SW CORNER OF       (KM)     PLT0250
     26.    C                   PLOTTING GRID.                                       PLT0260
     27.    C       YMIN        NORTH-SOUTH COORDINATE OF SW CORNER OF     (KM)     PLT0270
     28.    C                   PLOTTING GRID.                                       PLT0280
     29.    C       XSIZE   EAST-WEST SIZE OF PLOTTING GRID     (KM)                 PLT0290
     30.    C       YSIZE   NORTH-SOUTH SIZE OF PLOTTING GRID   (KM)                 PLT0300
     31.    C       AXL  LENGTH OF X AXIS IN INCHES                                  PLT0310
     32.    C       AYL LENGTH OF Y AXIS IN INCHES                                   PLT0320
     33.          XMAX=XMIN+XSIZE                                                    PLT0330
     34.          YMAX=YMIN+YSIZE                                                    PLT0340
     35.    C        INITIALIZE PLOT AND DEFINE ORIGIN.                              PLT0350
     36.          CALL PLOTS (I,1,14)                                                PLT0360
     37.          CALL PLOT (3.,2.,-3)                                               PLT0370
     38.          XPAGE=0.                                                           PLT0380
     39.          YPAGE=0.                                                           PLT0390
     40.          XPG=0.                                                             PLT0400
     41.          YPG=0.                                                             PLT0410
     42.          IF (IPLT.NE.1.AND.IPLT.NE.3) GO TO 90                              PLT0420
     43.          DO 80 IRP=1,NUMR                                                   PLT0430
  1  44.          CMAX=0.                                                            PLT0440
  1  45.          IVAL=0                                                             PLT0450
  1  46.          READ (22) NTIME,ITIME,NREC                                         PLT0460
  1  47.          DO 10 I=1,NREC                                                     PLT0470
  2  48.    10    READ (22) XREC(I),YREC(I),Z                                        PLT0480
  1  49.          XRR=XREC(IREC(IRP))                                                PLT0490
  1  50.          YRR=YREC(IREC(IRP))                                                PLT0500
  1  51.    20    READ (22) IT,ISTEP                                                 PLT0510
  1  52.          TIMIN=((IT-1)*ITIME)/60.                                           PLT0520
  1  53.          IR=MOD(IT,ITPT)                                                    PLT0530
  1  54.          IF (IR.EQ.0) TIMIN=((IT-ITPT)*ITIME)/60.                           PLT0540
  1  55.          IF (ITPT.GE.999) TIMIN=0.                                          PLT0550
  1  56.    30    READ (22) ITM,(CONC(K),K=1,NREC)                                   PLT0560
  1  57.          IVAL=IVAL+1                                                        PLT0570
  1  58.          TIME(IVAL)=ITM                                                     PLT0580
  1  59.          CONT(IVAL)=CONC(IREC(IRP))                                         PLT0590
  1  60.          IF (CMAX.LT.CONT(IVAL)) CMAX=CONT(IVAL)                            PLT0600
  1  61.          IF (ITM.LT.IT*ITIME) GO TO 30                                      PLT0610
  1  62.          READ (22) NPUFF                                                    PLT0620
  1  63.          DO 40 NP=1,NPUFF                                                   PLT0630
  2  64.    40    READ (22) D1,D2,D3,D4,D5                                           PLT0640
  1  65.          IF (ITPT.GT.999) GO TO 60                                          PLT0650
  1  66.          IF (IR.NE.0) GO TO 60                                              PLT0660
  1  67.    50    CONTINUE                                                           PLT0670
  1  68.          XM=XSI+2.                                                          PLT0680
  1  69.    C       DEFINE NEW ORIGIN FOR NEXT PLOT.                                 PLT0690
  1  70.          CALL PLOT (XM,0.,-3)                                               PLT0700
  1  71.          CALL PLTCON (IVAL,IYR,XRR,YRR,CMAX)                                PLT0710
  1  72.          IVAL=0                                                             PLT0720
  1  73.          IF (IT.LT.NTIME) GO TO 20                                          PLT0730
  1  74.          GO TO 70                                                           PLT0740
  1  75.    60    CONTINUE                                                           PLT0750
```

```
1       76.             IF (IT.LT.NTIME) GO TO 20                                       PLT0760
1       77.             IF (IT.EQ.NTIME.AND.ITPT.GT.999) GO TO 50                       PLT0770
1       78.             WRITE (6,170)                                                   PLT0780
1       79.     70      CONTINUE                                                        PLT0790
1       80.             REWIND 22                                                       PLT0800
1       81.     80      CONTINUE                                                        PLT0810
        82.     90      CONTINUE                                                        PLT0820
        83.             IF (IPLT.EQ.1) GO TO 160                                        PLT0830
        84.             IF (IPLT.EQ.2.OR.IPLT.EQ.3) GO TO 100                           PLT0840
        85.             GO TO 150                                                       PLT0850
        86.     100     CONTINUE                                                        PLT0860
        87.             READ (22) NTIME,ITIME,NREC                                      PLT0870
        88.             DO 110 I=1,NREC                                                 PLT0880
1       89.     110     READ (22) XREC(I),YREC(I),Z                                     PLT0890
        90.     120     READ (22) IT,ISTEP                                              PLT0900
        91.     130     READ (22) ITM,(CONC(K),K=1,NREC)                                PLT0910
        92.             IF (ITM.LT.IT*ITIME) GO TO 130                                  PLT0920
        93.             READ (22) NPUFF                                                 PLT0930
        94.             DO 140 NP=1,NPUFF                                               PLT0940
1       95.             READ (22) XPUF(NP),YPUF(NP),Z,SY,SZ                             PLT0950
1       96.     140     SRR(NP)=SY/1000.                                                PLT0960
        97.             XM=AXL+2                                                        PLT0970
        98.             IF (XSI.GT.AXL) XM=XSI+2.                                       PLT0980
        99.     C         DEFINE NEW ORIGIN FOR NEXT PLOT.                              PLT0990
       100.             CALL PLOT (XM,0.,-3)                                            PLT1000
       101.             CALL PLTTRJ (NPUFF)                                             PLT1010
       102.             IF (IT.LT.NTIME) GO TO 120                                      PLT1020
       103.             GO TO 160                                                       PLT1030
       104.     150     WRITE (6,180) IPLT                                              PLT1040
       105.     160     CONTINUE                                                        PLT1050
       106.             CALL PLOT (10.,0.,3)                                            PLT1060
       107.             CALL PLOT (10.,0.,999)                                          PLT1070
       108.             STOP                                                            PLT1080
       109.     C                                                                       PLT1090
       110.     170     FORMAT (5X,'NTIME IS NOT AN EVEN MULTIPLE OF ITPT',/)           PLT1100
       111.     180     FORMAT (5X,'IPLT= ',I2,'  IPLT MUST HAVE A VALUE OF 1,2,OR 3',/) PLT1110
       112.     C                                                                       PLT1120
       113.             END                                                             PLT1130
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      114.          SUBROUTINE PLTCON(IVAL,IYR,XR,YR,CMAX)                          PLC0010
      115.          COMMON /PUPCON/ XPG,YPG,XSI,YSI,CONT(3600),TIME(3600),TIMIN     PLC0020
      116.          DIMENSION XRAY(3600),CON(3600)                                  PLC0030
      117.          IF(IYR.LE.0) IYR=6                                              PLC0040
      118.          DO 10 I=1,IVAL                                                  PLC0050
1     119.          CT=CONT(I)                                                      PLC0060
1     120.          IF(CT.LT.1.0E-35) CT=1.0E-35                                    PLC0070
1     121.          CON(I)=CT                                                       PLC0080
1     122.    10    XRAY(I)=TIME(I)/60.                                             PLC0090
1     123.    C       XC IS SCALE FOR X AXIS.                                       PLC0100
      124.          XC=(XRAY(IVAL)-TIMIN)/XSI                                       PLC0110
      125.          DO 20 I=1,70                                                    PLC0120
1     126.          IP=-(35-I)                                                      PLC0130
1     127.          UPVAL=CMAX/10.**IP                                              PLC0140
1     128.          IF(UPVAL.LT.1.) GO TO 30                                        PLC0150
1     129.    20    CONTINUE                                                        PLC0160
      130.    30    BMAX=10.**IP                                                    PLC0170
      131.          BMIN=BMAX/10.**IYR                                              PLC0180
      132.          DO 40 I=1,IVAL                                                  PLC0190
1     133.    40    IF(CON(I).LT.BMIN) CON(I)=BMIN                                  PLC0200
      134.          YC=IYR/YSI                                                      PLC0210
      135.    C       YC IS SCALE FOR Y AXIS.                                       PLC0220
      136.    C       YSI LENGTH OF Y AXIS                                          PLC0230
      137.    C       PLOT Y AXIS AT XPG AND XSI.                                   PLC0240
      138.          CALL LGAXS(XPG,YPG,22HCONCENTRATION (G/M**3),22,YSI,90.,        PLC0250
     1BMIN,YC)                                                                      PLC0260
      140.          CALL LGAXS(XSI,YPG,22HCONCENTRATION (G/M**3),-22,YSI,90.,       PLC0270
     1BMIN,YC)                                                                      PLC0280
      142.    C       PLOT X AXIS AT YPG AND YSI.                                   PLC0290
      143.          CALL AXIS(XPG,YPG,14HTIME (MINUTES),-14,XSI,0.,TIMIN,XC)        PLC0300
      144.          CALL AXIS(XPG,YSI,1H ,1,XSI,0.,TIMIN,XC)                        PLC0310
      145.          XRAY(IVAL+1)=TIMIN                                              PLC0320
      146.          XRAY(IVAL+2)=XC                                                 PLC0330
      147.          CON(IVAL+1)=BMIN                                                PLC0340
      148.          CON(IVAL+2)=YC                                                  PLC0350
      149.    C       PLOT DATA.                                                    PLC0360
      150.          CALL LGLIN(XRAY,CON,IVAL,1,0,0,1)                               PLC0370
      151.          XP=XPG+1                                                        PLC0380
      152.          YP=YPG+YSI+0.5                                                  PLC0390
      153.    C       WRITE TITLE AT TOP OF PLOT.                                   PLC0400
      154.          CALL SYMBOL(XP,YP,0.14,9HRECEPTOR ,0.,9)                        PLC0410
      155.          CALL NUMBER(999.0,YP,0.14,XR,0.,3)                              PLC0420
      156.          CALL SYMBOL(999.0,YP,0.14,3H , ,0.,3)                           PLC0430
      157.          CALL NUMBER(999.0,YP,0.14,YR,0.,3)                              PLC0440
      158.          RETURN                                                          PLC0450
      159.          END                                                             PLC0460
```

```
      SUBROUTINE PLTTRJ(NPUFF)                                          PLJ0010
      COMMON /PUFTRJ/ XPAGE,YPAGE,XPUF(600),YPUF(600),SRR(600),         PLJ0020
     1XMIN,XMAX,YMIN,YMAX,AXL,AYL,XREC(25),YREC(25),NREC                PLJ0030
      DIMENSION XP(602),YP(602)                                         PLJ0040
      DO 10 I=1,NPUFF                                                   PLJ0050
      XP(I)=XPUF(I)/1000.                                               PLJ0060
   10 YP(I)=YPUF(I)/1000.                                               PLJ0070
      XC=(XMAX-XMIN)/AXL                                                PLJ0080
      YC=(YMAX-YMIN)/AYL                                                PLJ0090
C       XC IS SCALE FOR X AXIS.                                         PLJ0100
C       YC IS SCALE FOR Y AXIS.                                         PLJ0110
      XP(NPUFF+1)=XMIN                                                  PLJ0120
      XP(NPUFF+2)=XC                                                    PLJ0130
      YP(NPUFF+1)=YMIN                                                  PLJ0140
      YP(NPUFF+2)=YC                                                    PLJ0150
C       PLOT X AXIS AT YPAGE AND YPP.                                   PLJ0160
      CALL AXIS(XPAGE,YPAGE,26HX(KM) EAST-WEST COORDINATE,-26,AXL,      PLJ0170
     10.,XMIN,XC)                                                       PLJ0180
      YPP=YPAGE+AYL                                                     PLJ0190
      XPP=XPAGE+AXL                                                     PLJ0200
      CALL AXIS(XPAGE,YPP,26HX(KM) EAST-WEST COORDINATE,26,AXL,         PLJ0210
     10.,XMIN,XC)                                                       PLJ0220
C       PLOT Y AXIS AT XPAGE AND XPP.                                   PLJ0230
      CALL AXIS(XPAGE,YPAGE,28HY(KM) NORTH-SOUTH COORDINATE,28,AYL,     PLJ0240
     190.,YMIN,YC)                                                      PLJ0250
      CALL AXIS(XPP,YPAGE,28HY(KM) NORTH-SOUTH COORDINATE,-28,AYL,      PLJ0260
     190.,YMIN,YC)                                                      PLJ0270
      DO 20 I=1,NPUFF                                                   PLJ0280
      X=(XP(I)+SRR(I)-XMIN)/XC                                          PLJ0290
      Y=(YP(I)-YMIN)/YC                                                 PLJ0300
      SR=SRR(I)/XC                                                      PLJ0310
C       DRAW CIRCLE AROUND PUFF CENTER, RADIUS= 1 SIGMA.                PLJ0320
      CALL CIRCL(X,Y,0.,360.,SR,SR,0.)                                  PLJ0330
   20 CONTINUE                                                          PLJ0340
      DO 30 I=1,NREC                                                    PLJ0350
      XI=I                                                              PLJ0360
      XR=(XREC(I)-XMIN)/XC                                              PLJ0370
      YR=(YREC(I)-YMIN)/YC                                              PLJ0380
C       PLOT RECEPTOR LOCATIONS.                                        PLJ0390
      CALL NUMBER(XR,YR,0.14,XI,0.,-1)                                  PLJ0400
   30 CONTINUE                                                          PLJ0410
C       PLOT LINE THROUGH PUFF CENTERS.                                 PLJ0420
      CALL LINE(XP,YP,NPUFF,1,0,0)                                      PLJ0430
      RETURN                                                            PLJ0440
      END                                                               PLJ0450
```

Date_____

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U. S. Environmental Protection Agency
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I would like to receive future revisions to the "INPUFF User's Guide."

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